U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-257 629

The Hawaii Sugar Industry Waste Study

Environmental Protection Agency

June 1971

BIBLIOGRAPHIC DATA SHEET	1. Report No.	2.	3. Recipient's Accession No. PB-257 629
4. Title and Subtitle The Hawaii Sugar Industry Waste Study			5. Report Date Jun 71
			6.
7. Author(s)			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Environmental Protection Agency San Francisco, California REgion IX			10. Project/Task/Work Unit No.
			11. Contract/Grant No.
12. Sponsoring Organization Name and Address			13. Type of Report & Period Covered
			14.

15. Supplementary Notes

16. Abstracts

The objectives of the study were: (1) To determine the magnitude, characteristics, and effects on the receiving water of waste discharges from sugar mill operations in the State of Hawaii; (2) to compare the magnitude and characteristics of runoff from the sugar cane fields with runoff from non-developed areas; (3) to identify remedial measures that would adequately control any observed pollution.

17. Key Words and Document Analysis. 17a. Descriptors

*Water pollution,
*Industrial wastes,
*Sugar crops,
*Hawaii,
Arsenic,
Runoff,
Sugar cane,
Water pollution abatement,
Industrial waste treatment,
Waste water reuse,
Grinding mills,
Sanitary engineering,
Oxygen,
Dissolved gases,
Bacteria,
Fishes,
Waste disposal,
North Pacific Ocean,
Irrigation,
Bioassay.

17b. Identifiers/Open-Ended Terms

*Sugar industry.

17c. COSATI Field/Group 13 B 2 D

18. Availability Statement National Technical Information Service Springfield, Virginia 22161	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 116p
	20. Security Class (This Page) UNCLASSIFIED	22. Price 5.50/2.25

266136

PB 257 629

THE HAWAII SUGAR INDUSTRY WASTE STUDY

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

116

TABLE OF CONTENTS

CHAPTER PAGE

I INTRODUCTION 1

Background.............................. 1
Objectives and Scope.................... 3
Acknowledgements........................ 4

II SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS 6

Summary................................. 5
Findings................................ 6
Conclusions............................. 9
Recommendations......................... 9

III THE STUDY AREA 11

Kauai................................... 11
Oahu.................................... 15
Maui.................................... 17
Hawaii.................................. 17

IV THE HAWAIIAN SUGAR CANE INDUSTRY 21

Field Operations........................ 21
Factory Operations...................... 22
Water Supply............................ 24
Waste Products Disposal................. 25

V WATER QUALITY STUDIES 27

General Studies......................... 27
Studies Related to Sugar Industry...... 30

VI MILL SURVEYS 33

General Characteristics................. 34
Bacteriological Results................. 35
Solids Results.......................... 40
Organic Results......................... 47
Nutrient Results........................ 51
Arsenic, Herbicides, and pH Results.... 55
Irrigation Water Results................ 56

COLOR ILLUSTRATIONS REPRODUCED
IN BLACK AND WHITE

TABLE OF CONTENTS
(Continued)

CHAPTER PAGE

VII OFFSHORE SURVEYS 58

General Characteristics.................. 58
Floating Trash and Bagasse.............. 59
Turbidity............................... 60
Bacteriological Densities............... 66
Nutrients............................... 70
Dissolved Oxygen........................ 74
Temperature............................. 75
Salinity................................ 75
Bottom Conditions....................... 79
Fish Populations........................ 90

VIII BIOASSAYS.............................. 95

IX RUNOFF STUDY........................... 97

X SELECTED BIBLIOGRAPHY.................. 105

LIST OF TABLES

TABLE PAGE

1 Sanitary Analyses of Wastewater Discharges from Ten Sugar Factories.................. 31

2 Geometric Mean Coliform Concentrations, Mill Surveys.............................. 38

3 Average Concentrations, Mill Surveys........ 43

4 Average Loadings, Mill Surveys.............. 44

5 Average Unit Waste Loadings from Survey Mills Wash Water.......................... 50

6 Analytical Results: Excess Irrigation Water (Tailwater) from McBryde Plantation....... 57

7 Bioassay Results........................... 95

8 Maximum and Minimum Analytical Concentrations, Runoff Study 1967-1968.................... 101

9 Measurements Obtained from Runoff of February 1, 1969.......................... 104

LIST OF FIGURES

FIGURE PAGE

1 Areas of Sugar Cane Cultivation............ 12

2 Location of Sugar Mills, Island of Kauai... 13

3 Location of Sugar Mills, Island of Oahu.... 16

4 Location of Sugar Mills, Island of Maui.... 18

5 Location of Sugar Mills, Island of Hawaii.. 19

6 Typical Hawaiian Sugar Mill Schematic...... 23

7 Geometric Mean Coliform Concentrations, Mill Surveys............................ 37

8 Average Solids Concentrations, Mill Surveys 41

9 Average Solids Loadings, Mill Surveys...... 42

10 Average Organic Concentrations, Mill Surveys 48

11 Average Organic Loadings, Mull Surveys..... 49

12 Average Nutrient Concentrations, Mill Surveys................................ 52

13 Average Nutrient Loadings, Mill Surveys.... 53

14 Surface Turbidity as Depth of Visibility, Honokaa Mill Discharge.................. 61

15 Surface Turbidity as Depth of Visibility, Pioneer Mill Discharge.................. 63

16 Surface Turbidity as Depth of Visibility, McBryde Mill Discharge.................. 65

LIST OF FIGURES
(Continued)

FIGURE PAGE

17 Total Coliform Concentrations, Honokaa Mill Offshore Waters.......................... 68

18 Total Coliform Concentrations, Pioneer Mill Offshore Waters.......................... 69

19 Total Phosphorus Values, Honokaa Mill Offshore Waters.......................... 72

20 Total Phosphorus Values, Pioneer Mill Offshore Waters.......................... 73

21 Extent of Coral Formations, Honokaa Mill Offshore Waters.......................... 80

22 Bottom Conditions, Honokaa Mill Outfall Area 81

23 Typical Bottom Conditions, Honokaa Mill Control Area.............................. 82

24 Bottom Conditions, Pioneer Mill Outfall Area.. 84

25 Typical Bottom Conditions, Pioneer Mill Control Area............................. 85

26 Bottom Conditions, Olokele Mill, West Outfall Area............................. 86

27 Bottom Conditions, Olokele Mill Control Area 87

28 Extent of Coral Formations, Olokele Mill Offshore Waters.......................... 89

29 Results of Fish Counts, Honokaa Mill Survey 91

LIST OF FIGURES
(Continued)

FIGURE PAGE

30 Results of Fish Counts, Pioneer Mill Survey 92

31 Results of Fish Counts, Olokele Mill Survey 93

32 Runoff Study Basin Locations.............. 98

33 Rainfall Versus Runoff, Undeveloped and Canefield Terrains...................... 100

34 Suspended Solids Discharge, Undeveloped and Canefield Terrains...................... 103

LIST OF PLATES

PLATE PAGE

1 Honokaa Mill Outfall, Bottom Formations in 18 feet of Water.......... 76

2 Honokaa Mill Outfall, Barren Substrate in 25 feet of Water.......... 76

3 Honokaa Mill Control Area, Boulder Zone at a Depth of 40 feet.......... 76

4 Pioneer Mill Outfall, Sea Urchin with Cane Trash in 10 Feet of Water.......... 76

5 Pioneer Mill Outfall, at Approximately 250 Yards.......... 77

6 Pioneer Mill Control Area, at Approximately 300 Yards.......... 77

7 Olokele Mill Outfall, at Kaumukani Point... 77

8 Olokele Mill Control Area, Several Species of Coral.......... 77

9 An Aerial View of the Olokele Sugar Mill... 78

10 Site of the Honokaa Mill Outfall Discharge. 78

11 The McBryde Sugar Mill.......... 78

12 The Pioneer Sugar Mill.......... 78

THE HAWAII SUGAR INDUSTRY WASTE STUDY

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

JUNE 1971

I. INTRODUCTION

BACKGROUND

The State of Hawaii is endowed with an excellent year-round climate, a profusion of natural scenic attractions, and a luxuriant landscape. These resources provide the basis for two of its larger and more important industries, agriculture and tourism.

The continued and prosperous coexistence of these major contributors to Hawaii's economy, however, is endangered. Wastes generated by agricultural activities, particularly sugar mill operations, are creating significant water pollution problems which threaten to interfere with the continued growth of the tourist industry.

Tourism is, and has been, a leading factor influencing growth in Hawaii throughout the postwar period. The basic trend within Hawaii today is directed toward spreading tourism to all of the islands. This has been accomplished by a major change in advertising which promotes all island attractions, thereby increasing the scope and appeal of Hawaii as a world travel center. The magnificent assets which Hawaii possesses as a resort area have been effectively marketed, and programs to tell its story are being accelerated.

The importance of pollution-free waters to tourism and recreation was brought out by the Federal Water Pollution Control Advisory Board, a Presidential Board, which met in Hawaii in June of 1963 and undertook an extensive tour of the islands in order to define the State's pollution problems. As a result of their visit, the Board passed the following resolution on September 18, 1963.

RESOLUTION NO. 2

Hawaii Pollution Problems

> "WHEREAS, The Federal Water Pollution Control Advisory Board, during a recent visit to the beautiful Islands of Hawaii, had an opportunity to see firsthand water pollution problems of our newest State; and
>
> WHEREAS, the Board made an extensive observation of military, municipal, industrial and agricultural pollution; and

WHEREAS, deplorable conditions of water and soil degradation were noted from these sources on the Islands of Oahu and Hawaii; and

WHEREAS, action to abate municipal and military pollution has been initiated; and

WHEREAS, coastal waters of both Islands are seriously affected by agricultural and milling practices employed in the sugar and pineapple industries; and

WHEREAS, recreational and tourist values, upon which the Islands depend so heavily, and also important fisheries resources, are adversely threatened by these sources of pollution; and

WHEREAS, there apparently are no current plans or programs under way to change those practices which are responsible for these pollution problems; and

WHEREAS, certain contemporary soil practices of mechanically harvesting sugar cane as well as present waste disposal methods of both the sugar and pineapple industries are contributing heavily to the coastal pollution...

NOW THEREFORE BE IT RESOLVED that the Federal Water Pollution Control Advisory Board feels that the solution of these problems is vital to the welfare of the State of Hawaii and the Nation; that better practices in the harvest of sugar cane would be in the best interest of soil conservation and pollution abatement; and that both the sugar and pineapple interests need to recognize the adverse effect they are having on the State's recreational economy.

BE IT FURTHER RESOLVED, that copies of this resolution be forwarded to the Secretary of Agriculture, to the Secretary of Health, Education, and Welfare, and to the Governor of Hawaii, respectfully recommending that studies be initiated which may lead to eventual reduction or elimination of these pollution sources.

BE IT FURTHER RESOLVED, that this Board recommend to the Secretary of Health, Education, and Welfare that he authorize forceful action, including enforcement authority if applicable, toward solution of the Islands pollution problems and periodically report to the Board progress being made."

Shortly after the Federal Board's report, the Hawaii Department of Health requested that a study be initiated which would lead to the eventual reduction or elimination of these pollution sources. The Hawaii Department of Health then requested that such a study be carried out by the U.S. Public Health Service[1] as provided for by Section 5(b) of the Federal Water Pollution Control Act. (P.L. 84-660). The study was initiated by the Federal Water Pollution Control Administration, successor to the U.S. Public Health Service, in November 1966 to investigate industrial wastes discharged by the Hawaiian sugar industry. This report describes the results of that study.

Specifically, the sugar cane grown in Hawaii is mechanically harvested and processed in 26 mills located on four of the State's six major islands. The unique harvesting procedures used in Hawaii require the mills to wash or launder the cane before extracting the sugar. The resulting soil-laden wash water is normally discharged into the ocean. Many of the mills also directly discharge their industrial processing wastewaters and sugar cane trash[2] and bagasse[3] into the ocean. Another major discharge emanating from the sugar cane industry is excess irrigation water (tailwater) and stormwater runoff from cultivated fields. These have pollutional characteristics similar to mill washwater.

OBJECTIVES AND SCOPE

The objectives of the study were: (1) to determine the magnitude, characteristics, and effects on the receiving water of waste discharges from sugar mill operations in the State of Hawaii; (2) to compare the magnitude and characteristics of runoff from the sugar cane fields with runoff from non-developed areas; (3) to identify remedial measures that would adequately control any observed pollution.

---

[1] Predecessor to the Federal Water Pollution Control Administration, U.S. Department of the Interior (1965); the Federal Water Quality Administration, U.S. Department of the Interior (April 3, 1970); and the present Environmental Protection Agency (December 2, 1970).

[2] Plant foliage, roots, broken stalks.

[3] The crushed remains of the sugar cane stalk following extraction of the juices in the mills. It resembles coarse sawdust or wood shavings.

In order to achieve these objectives, the study was carried out in five phases:

1. A preliminary survey of all sugar mills and plantations was made to compare their processes and agricultural practices.

2. Intensive three-day surveys were conducted in the summer, fall, and spring at representative mills to determine the quality and quantity of the waste throughout the year.

3. Studies of ocean waters and bottom conditions were conducted offshore from the representative mills. Studies were made in control areas that were nearby but beyond the influence of the mills. Conditions found in the discharge areas were compared with those found in control areas to evaluate the effects of mill operations on the quality and bottom characteristics of the adjacent coastal waters.

4. Short-term bioassays (96-hour, or less) were conducted on local species of fish to indicate the short-term toxicity of mill waste and tail-waters.

5. Automated sampling and flow-monitoring apparatus were installed at the outlets of two small drainage basins, one under sugar cane cultivation and one in a nearly natural state. This equipment was used to measure the quality and quantity of the runoff from the two basins.

ACKNOWLEDGEMENTS

The study was made possible through the assistance and cooperation of the following organizations:

Department of Health, State of Hawaii
Hawaiian Sugar Planters Association
Honokaa Sugar Company

McBryde Sugar Company
Oahu Sugar Company
Pioneer Mill Company
University of Hawaii, Department of Oceanography
U.S. Geological Survey, Department of the Interior
U.S. Navy, Department of Defense
Waialua Agricultural Company

Special acknowledgement is given to all other sugar mills in the State of Hawaii for their willingness to cooperate with the study.

Valuable assistance was also provided by the following organizations:

Department of Land and Natural Resources, State of Hawaii
University of Hawaii, School of Public Health
Soil Conservation Service, Department of Agriculture

This study was planned and conducted under the direct supervision of Robert J. Burm, Sanitary Engineer, who co-authored the preliminary draft report with Donald E. Morris, Aquatic Biologist. They were assisted in the field studies by: Martin J.K. McMorrow, Sanitary Engineer; Lloyd P. Blaine, Biological Aid; Bernard L. Shiratori, Chemist; Vicki H. Tsuhako, Secretary, and others. The final report was assembled and edited by Charles T. Bourns, Physical Science Administrator.

II. SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

The Environmental Protection Agency conducted a study of water quality problems related to the discharge of sugar mill wastes in Hawaii during the period November 1966 through September 1968. A preliminary industrial process survey was made of all 26 sugar mills located in the State of Hawaii. Of these mills, the following three mills were chosen for detailed in-plant surveys: Pioneer Mill, Honokaa Mill, and McBryde Mill. More than 6000 chemical, physical, and bacteriological measurements were made. For offshore surveys, three mills were chosen: Pioneer Mill, Honokaa Mill, and Olokele Mill. Inadvertent closing of the Olokele Mill because of weather conditions, however, necessitated offshore studies of the McBryde Mill toward the end of the survey.

FINDINGS

The data show that sugar mill waste water (mill-processing water and cane-wash water) as well as irrigation water (tailwater) and storm water runoff from fields contain large amounts of oxygen-consuming materials, suspended solids, nutrients, and bacteria.

Excess irrigation waters and storm water runoff, while shown to be similar to mill waste water, were usually found to contain lower concentrations of all pollutants.

Average sugar production at each of the three mills studied at the time of the in-plant surveys was 210 tons per day. The mill wash water contained, per ton of raw sugar produced, an average of 1,850 pounds of suspended solids; 1,750 pounds of settleable solids; 650 pounds of oxygen-consuming material, as measured by chemical oxygen demand; 12 pounds of total nitrogen; and 5 pounds of total phosphorus. The bacterial densities found in the mill wash water averaged 4,850,000 total coliform organisms and 130,000 fecal coliform organisms/100 ml. Waste-flow rates at each of the mills were between 5 and 10 million gallons per day during the survey.

On the four sugar-producing islands of Hawaii, Kauai, Oahu, and Maui, many of the mills discharge wastes into the ocean near areas where surfing, fishing, swimming, and other recreational activities take place. Where these discharges occur, the high concentrations of coliform indicate a possible health hazard to the populace using these waters for body-contact sports.

A few mills on all four islands utilize some controls or waste treatment process such as clarifiers or sedimentation ponds, or utilize waste waters in irrigation. These measures substantially reduce or abate the discharge of noxious wastes. Where sedimentation of mill wastes was practiced, removal of settleable solids reached 98 per cent, but the remaining suspended material in the effluent, when discharged to the ocean, caused large areas of discoloration. Significant removals were also noted for suspended solids, biochemical oxygen demand, chemical oxygen demand, total organic carbon, total phosphorus, and total nitrogen.

Offshore surveys revealed that the ocean waters, when not influenced by runoff or mill discharges, had a transparency in excess of 50 feet, as measured by a Secchi disc. Also, total coliform densities were consistently less than 100 organisms/100 ml, and other quality constituents were within ranges considered normal for sea water.

The wastes discharged in mill effluents, irrigation tailwater, and storm water runoff affect several significant water usages. The effects of mill waste discharges on ocean waters, as evidenced by increases in turbidity were noticeable for distances of up to four miles from the point of discharge. In many areas a brown or green discoloration was noticeable for more than two miles beyond the waste outfalls. The volcanic soils of the Hawaiian Islands are composed of extremely fine particles. When suspended in cane wash water, irrigation tailwater, or storm water (all fresh water) they impart turbidity of an apparent red or brown color. When discharged to the ocean, the fresh water "floats" as a relatively thin layer on the surface, producing large areas of discoloration. Secchi disc readings of only a few inches were measured near all three sugar mill outfalls studied.

Total coliform densities were much higher in the affected waters and on one occasion were found to exceed 1,000,000 organisms/100 ml. Total phosphorus values as high as 0.29 mg/l were observed, with values above normal sea water observed for more than one mile from the mill outfalls. Dissolved oxygen, salinity, and temperature were found to be relatively unaffected by the mill discharges.

At least eight of the mills on the island of Hawaii and two mills on the island of Kauai regularly discharge cane trash and/or bagasse to the ocean. Floating mats of this material can extend over a mile, with widths varying from a few feet to over 200 feet, creating a hazard to navigation and an aesthetic nuisance. The deleterious effects of cane trash and bagasse on the marine ecology were not studied in detail, but it was observed that under strong wind conditions, the mats were washed up along the coastline, covering the biota, beaches, and rocks. The floating mats interfered with the operation of the vessel which was used in this study. Boat operators in these same areas reported interference with navigation and hazards to safety resulting from the floating materials.

The aesthetically offensive conditions created by floatable materials, sludge deposits, and brown and green discoloration of large ocean areas due to sugar mill discharges pose a threat to the tourist industry. These adverse conditions are diametrically opposed to the goals of that industry which describes "the continuous blue, sparkling waters of the State" to potential tourists.

Several short term bioassays were conducted using wash water and tailwater. The mill wastes appear to be toxic to Nehu, an important tuna bait fish. However, three other local species of fish subjected to the tests were tolerant of the wastes.

The sugar mill wastes contain levels of the organic materials nitrogen and phosphorus in sufficient amounts to produce adverse ecological changes if discharged to confined receiving waters. Even after existing treatment processes, mill wastes are capable of exerting an oxygen depletion if discharged into coastal bays or other areas with limited circulation.

When this study was initiated, water quality standards had not been established for the State of Hawaii. Before the study was completed, however, State and Federal water quality standards had been adopted by the State and approved by the Federal Government.

Findings of this study indicate that the sugar industry is discharging materials to the ocean which result in violations of the following Water Quality Standards of the State of Hawaii:

1. All water shall be free of substances attributable to discharges or wastes as follows:

   a. Material that will settle to form objectionable deposits (sediment, cane trash and bagasse);

b. Floating debris and other matter (trash and bagasse);

c. Substances producing objectionable turbidity and color (sediment);

d. Materials...in concentrations or combinations which are toxic or produce undesirable physiological responses in human, fish and other animal life and plants (organic matter, bacteria, nutrients);

e. All waters shall also be free from soil particles resulting from erosion on land...(sediment, turbidity, color);

2. Microbiological requirements (bacteria);

3. Nutrient materials (nutrients).

CONCLUSIONS

1. It is practicable to control wastes from the harvesting and milling operations of the sugar mills, including suspended material, soil particles, trash, bagasse, organic material, nutrients, and bacteria.

2. It is practicable to implement soil conservation and sediment control practices as required by Section 37-A-6-A of the Water Quality Standards of the State of Hawaii, which provides that "these standards shall be deemed met if it can be shown that the land on which the erosion occurred or is occurring is being managed in accordance with soil conservation practices acceptable to the Director, and that a comprehensive conservation program is being actively pursued or that the discharge has received the best practicable treatment or control." In agricultural practice, however, soil conservation alone for control of sediment may not be completely effective in eliminating turbidity and color of waste discharges.

RECOMMENDATIONS

To enhance water quality to the level described in the Water Quality Standards of the State of Hawaii in those coastal areas now influenced by the discharges from Hawaiian sugar plantations, the following changes in operating conditions should be made:

1. The discharge of trash and bagasse to coastal waters should be discontinued.

2. All discharges should be treated or controlled to the necessary degree required for compliance with the Water Quality Standards of the State of Hawaii.

3. Whenever excess irrigation water (tailwater) and storm runoff waters from cultivated fields are now discharged to coastal waters, every possible effort should be made to minimize and control these discharges through improvements in irrigation facilities and management, interim storage and reuse of irrigation tailwater and storm water run-off, and adoption of soil and water conservation measures.

III. THE STUDY AREA

The Hawaiian Islands are a sea-mount island chain consisting of more than a score of islands which extend from Kure and Midway Islands in the west to the island of Hawaii in the east, a distance of approximately 1,600 miles. The islands were formed from volcanoes which today are either dormant or active.

In general, the island chain lies between 19 and 28 degrees north of the equator and is situated in the north central portion of the Pacific Ocean. The area of the islands totals 6,435 square miles or 4,118,400 acres, a territory roughly equivalent to the combined areas of the States of Connecticut and Rhode Island. Hawaii Island is the largest land mass, comprising approximately two-thirds of the total land area.

Only seven of the larger and western most islands are inhabited, excluding Midway Island which houses a U.S. Coast Guard station. Approximately one million people live on these islands. Other than military activities their principal industries, listed in descending order of economic importance, are tourism, agriculture, and commerce.

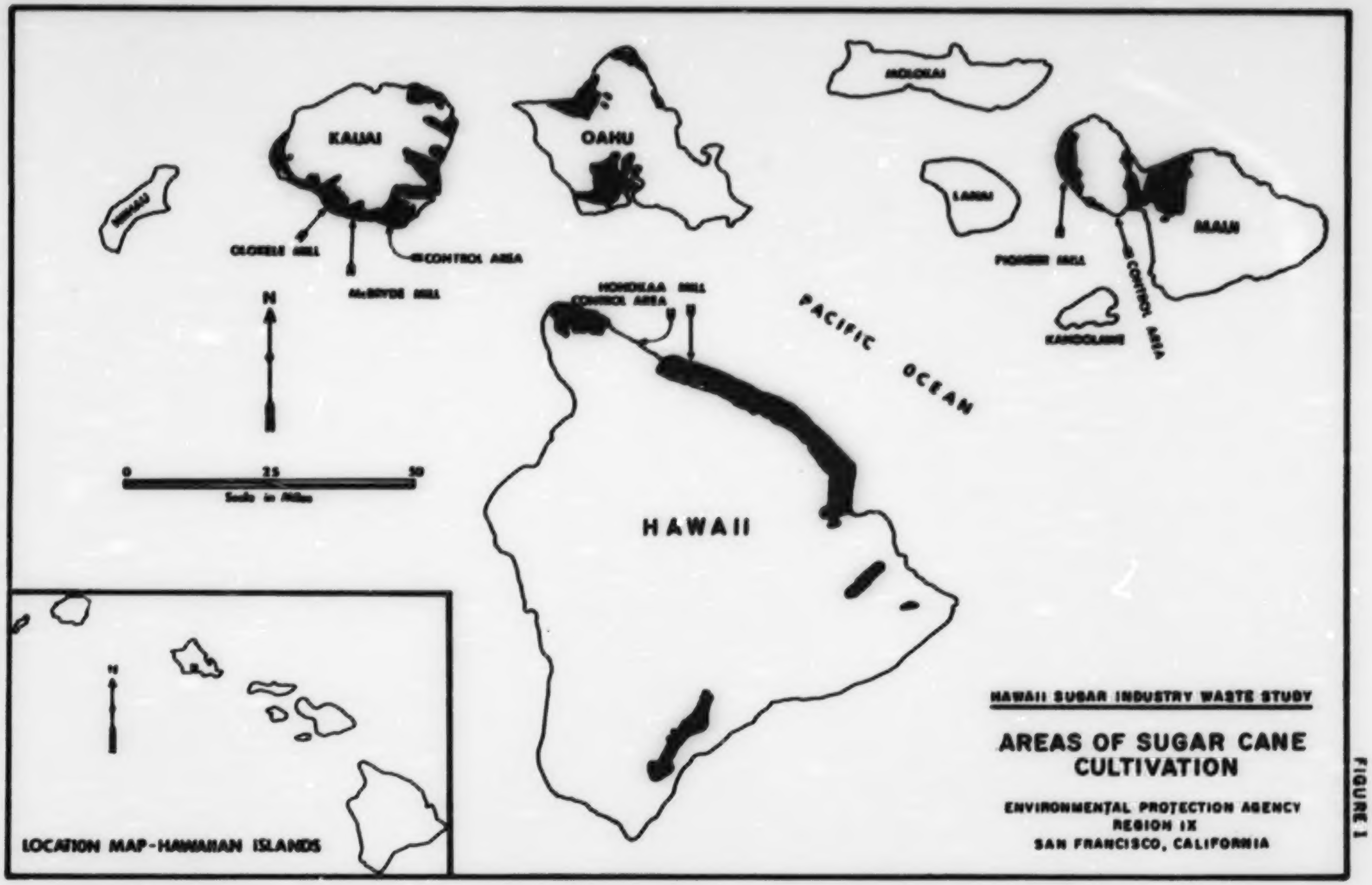
The island group became a territory of the United States in 1900, and in 1959 was officially admitted to the Union as the fiftieth State.

Even though the islands lie within the North Tropic Zone, each one that is inhabited has a distinctive climate and geography which has influenced its pattern of population, economy, and development. Therefore a description of each, with present and proposed usages relative to the sugar industry, is relevant to this study (Figure 1).

KAUAI

The island of Kauai is composed essentially from the remnant of a single volcanic dome (Figure 2). The northwest quadrant of the island has a rugged shoreline with sea cliffs exceeding 1000 feet. Its coastal waters have been classified under the State of Hawaii Water Quality Standards for preservation as an oceanographic wilderness area. The remaining three quadrants of the island consist of more gently sloping land which is used extensively for agriculture and ranching. These quadrants contain more miles of sandy beaches than the combined total beach area of all other islands in the

FIGURE 1

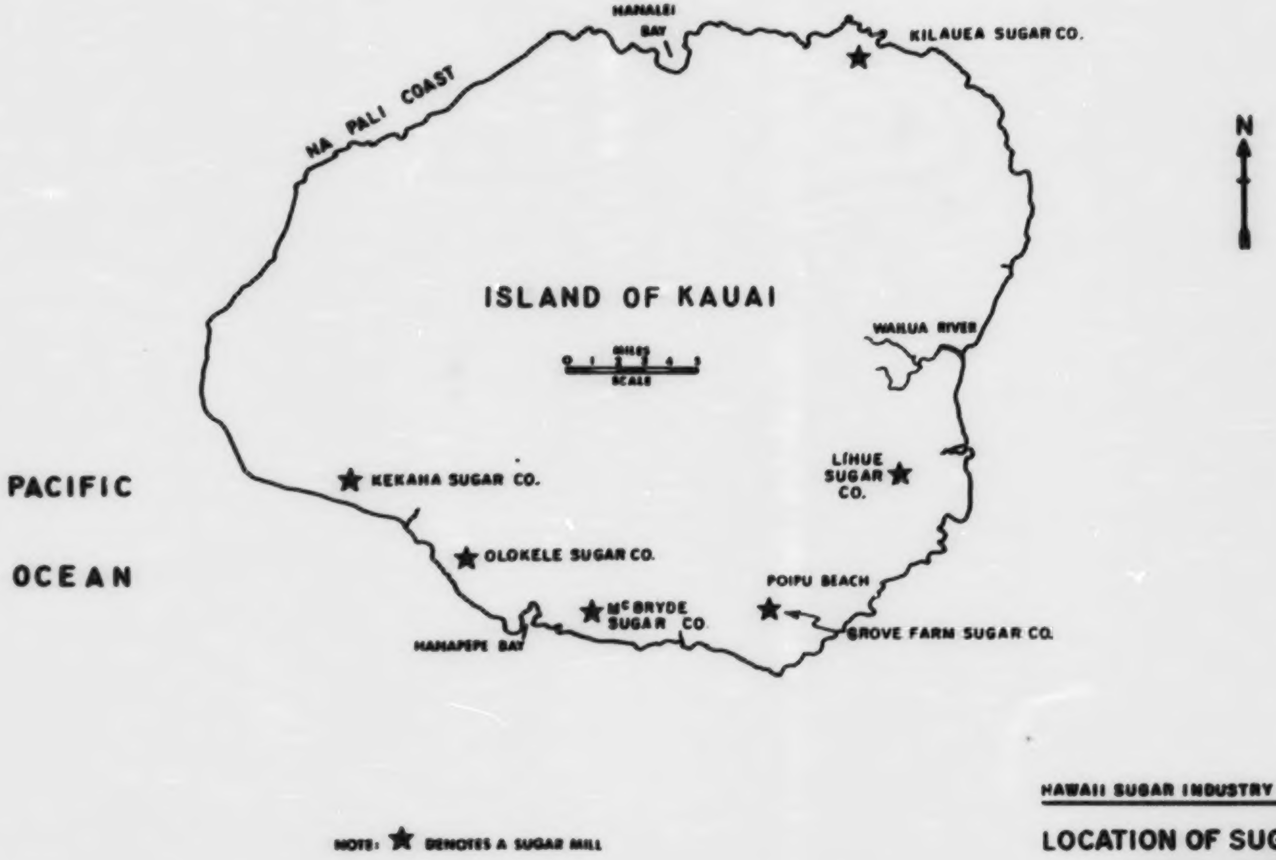

NIIHAU
KAUAI
OLOKELE MILL
McBRYDE MILL
CONTROL AREA
OAHU
MOLOKAI
LANAI
MAUI
PIONEER MILL
CONTROL AREA
KAHOOLAWE
HONOKAA MILL
CONTROL AREA
PACIFIC OCEAN
HAWAII
N
0
25
50
Scale in Miles
N
LOCATION MAP-HAWAIIAN ISLANDS

HAWAII SUGAR INDUSTRY WASTE STUDY

AREAS OF SUGAR CANE CULTIVATION

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

FIGURE 2


HANALEI BAY
KILAUEA SUGAR CO.
NA PALI COAST
N
ISLAND OF KAUAI
WAILUA RIVER
MILES
0 1 2 3 4 5
SCALE
PACIFIC
OCEAN
KEKAHA SUGAR CO.
LIHUE SUGAR CO.
OLOKELE SUGAR CO.
POIPU BEACH
McBRYDE SUGAR CO.
GROVE FARM SUGAR CO.
HANAPEPE BAY
NOTE: ★ DENOTES A SUGAR MILL

HAWAII SUGAR INDUSTRY WASTE STUDY

LOCATION OF SUGAR MILLS
ISLAND OF KAUAI

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

chain, and the associated coastal waters are extensively used for swimming, surfing, and sport fishing.

The northeast quadrant of Kauai extends from Hanalei Bay in the north to the mouth of the Wailua River in the east. A major resort hotel borders Hanalei Bay, and others are expected to develop there in the future. The land between the Bay and the Wailua River is used primarily for agriculture, pasture, and small population centers. At the mouth of the Wailua River are a resort hotel and a few public parks, with additional resort development expected in the area soon. The coastline has ample sandy beaches and future parks have been proposed along the entire shore.

Mount Waialeale (elevation 5,080 feet) has a reputation for being the wettest spot on earth and its average annual rainfall exceeds 430 inches. This quadrant, in general, is well watered and irrigation is practiced only near the coastline and in the valleys for rice and taro production. The principle agriculture is sugar cane, pineapple and pasture. The Kilauea Sugar Mill is located in the center of this quadrant, near the coast.

The southeast quadrant of the island, extending from the Wailua River to Hanapepe Bay, contains agricultural and pasture lands, undeveloped areas, two large and several small population centers, two commercial harbors, and a resort complex of several hotels in the Poipu Beach area, which is expected to undergo further expansion. There is a large public park and golf course along the coastline near the Wailua River. Although sandy beaches are not as plentiful as those found in the northeast quadrant, several good beaches exist, and plans have been made to develop these into public parks. Sugar cane is the principal agriculture and there are three sugar mills in this quadrant. The area is semi-arid and irrigation is required for agriculture at the lower elevations, although torrential rainfall occurs during the rainy season.

The southwest quadrant of the island, stretching from Hanapepe Bay to the Na Pali Coast, contains agricultural and undeveloped land, Bonham Air Force Base, and two small public parks. The beaches are predominantly sandy and run almost continuously from one side of the quadrant to the other. A public park and resort area have been proposed at Kekaha and also north of Bonham Air Force Base. Sugar cane is the principle crop and there are two sugar mills in this area. The climate is generally arid and irrigation is necessary for sugar cane production.

OAHU

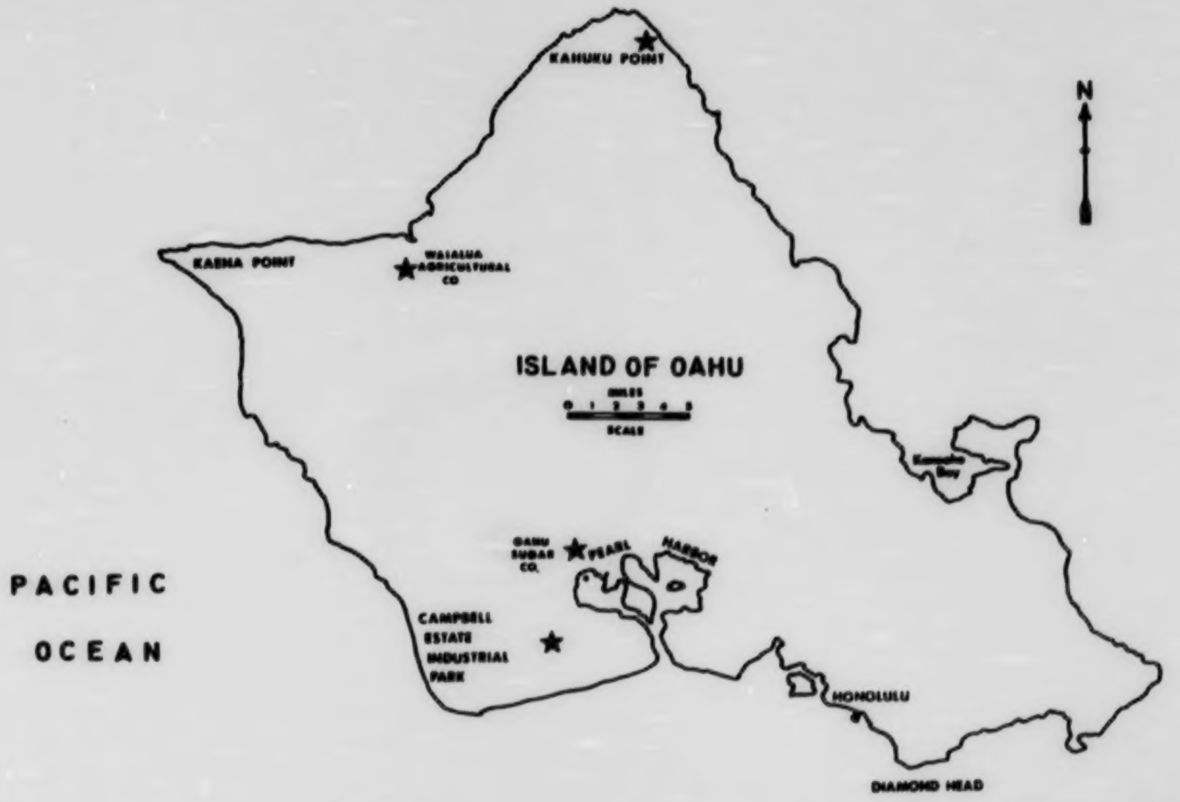
The island of Oahu is oriented in a northwest-southeast direction in the Hawaiian Island chain (Figure 3). Geographically, two parallel mountain ranges formed by extinct volcanoes, with a broad valley between, make up the island. Each mountain range is also flanked by relatively broad coastal plains. The southeastern portion of the island contains a chain of dormant volcanoes, the most well-known being Punchbowl, Diamond Head, and Koko Head. Since sugar cane is grown on the south-central, southeast, north, and northeast portions of the island, only these coastline areas will be described.

The shoreline along the south-central to southwest coast of Oahu is a predominantly military and industrial complex consisting of the Pearl Harbor Naval Base, Barbers Point Naval Air Station, Campbell Industrial Park, and two population centers. Several recreational beaches are located on the military bases. The State of Hawaii plans to have only a small public beach park located on this coastline area; however, many believe that increasing population pressures will cause the Navy to relinquish control of Pearl Harbor's West Loch resulting in further urban development. Sugar is grown and milled in this area by two plantations.

The northern coast of the island, extending from Kaena Point to Kahuku Point, consists primarily of a small airfield, agricultural land, two population centers, private beach homes, and several public beach parks. The shoreline contains approximately twenty miles of sandy beaches; however, high surf often limits the recreational usage of these waters. Additional public beach parks and resort development is anticipated in the future. There is only one sugar mill in this area.

The northeastern coast of Oahu stretching from Kahuku Point to Kahana Bay, consists of agricultural and grazing land, small population centers, private beach homes, and small public parks. The shoreline is composed primarily of sand or gravel, and many public beach parks have been proposed. One sugar mill is located in this area.

FIGURE 3


KAHUKU POINT
N
KAENA POINT
WAIALUA AGRICULTURAL CO
ISLAND OF OAHU
MILES
0 1 2 3 4 5
SCALE
Kaneohe Bay
OAHU SUGAR CO.
PEARL HARBOR
PACIFIC OCEAN
CAMPBELL ESTATE INDUSTRIAL PARK
HONOLULU
DIAMOND HEAD

NOTE: ★ DENOTES A SUGAR MILL

HAWAII SUGAR INDUSTRY WASTE STUDY

LOCATION OF SUGAR MILLS
ISLAND OF OAHU

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

MAUI

Maui is made up of two large volcanic cones joined together by an eight-mile isthmus or valley which was formed by overlapping lava flows (Figure 4). Since sugar is grown on the isthmus and on the western slopes of the West Maui Mountains, descriptions will be limited to these areas.

The area adjoining the northern coast of the valley contains primarily agricultural and grazing lands. Also located there are two population centers, a commercial harbor, airport, golf course, and several resort hotels. The north coastline has sandy beaches and bedrock in about equal proportions, and several sections have been proposed as sites for public beach parks and hotel expansion. There are three sugar mills in this area.

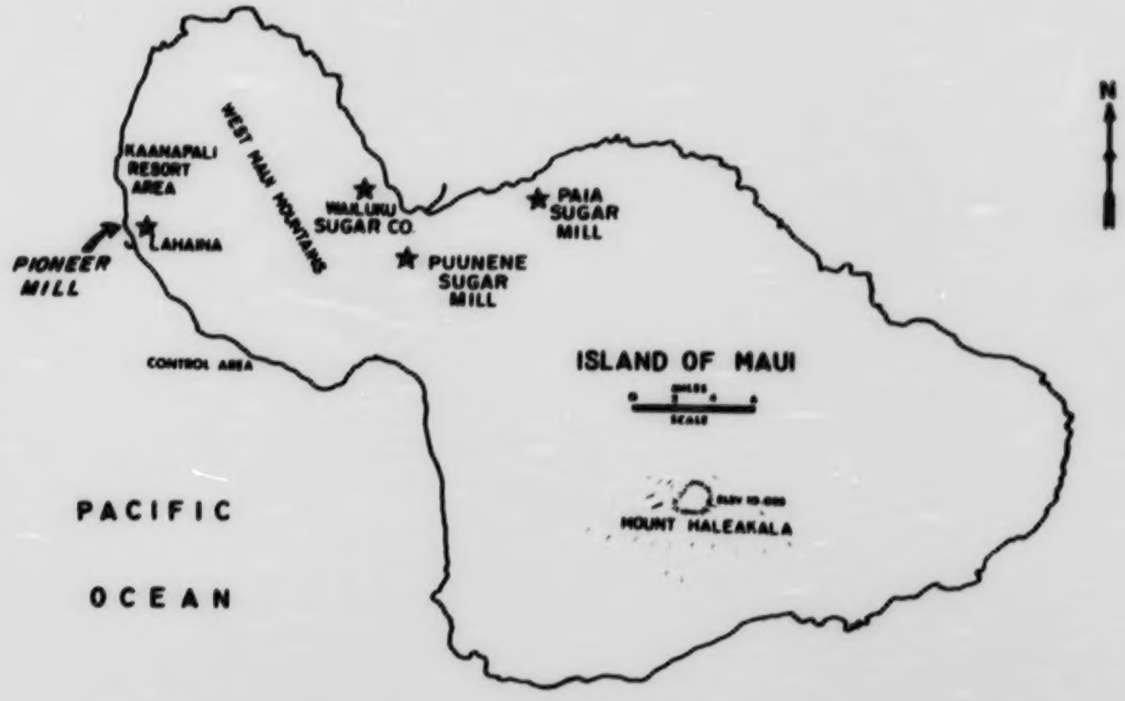
The area adjoining the southern coast of the valley consists of agricultural and open land, an abandoned fish pond, a small-boat harbor, and private homes. The southern shoreline of the isthmus is primarily sandy beach, and proposals exist to develop resort areas and facilities for private and public recreational use. There are no sugar mills in this area. Cane which is grown and harvested is carried by truck to mills in the north coast area.

The southwest coast of the West Maui Mountains contains agricultural and undeveloped land, one population center (Lahaina), a small-boat harbor, a golf course, small public parks, and an extensive, rapidly developing resort area. About half of the shoreline is sandy beaches. The town of Lahaina, formerly the capital of Hawaii, is the target of considerable effort aimed at historic restoration for purposes of tourism. Pressure is also being exerted by both public and private interests for development of the coastline northwest of Lahaina into a recreation area, while public beach parks are being proposed for location southeast of the town. There is one sugar mill in the area.

HAWAII

Hawaii, the largest island of the State, is formed from five separate volcanoes, two of which reach an elevation of nearly 14,000 feet (Figure 5). Of the five

FIGURE 4


N
KAANAPALI RESORT AREA
WEST MAUI MOUNTAINS
WAILUKU SUGAR CO.
PAIA SUGAR MILL
LAHAINA
PIONEER MILL
PUUNENE SUGAR MILL
CONTROL AREA
ISLAND OF MAUI
0
MILES
SCALE
ELEV 10,023
MOUNT HALEAKALA
PACIFIC
OCEAN

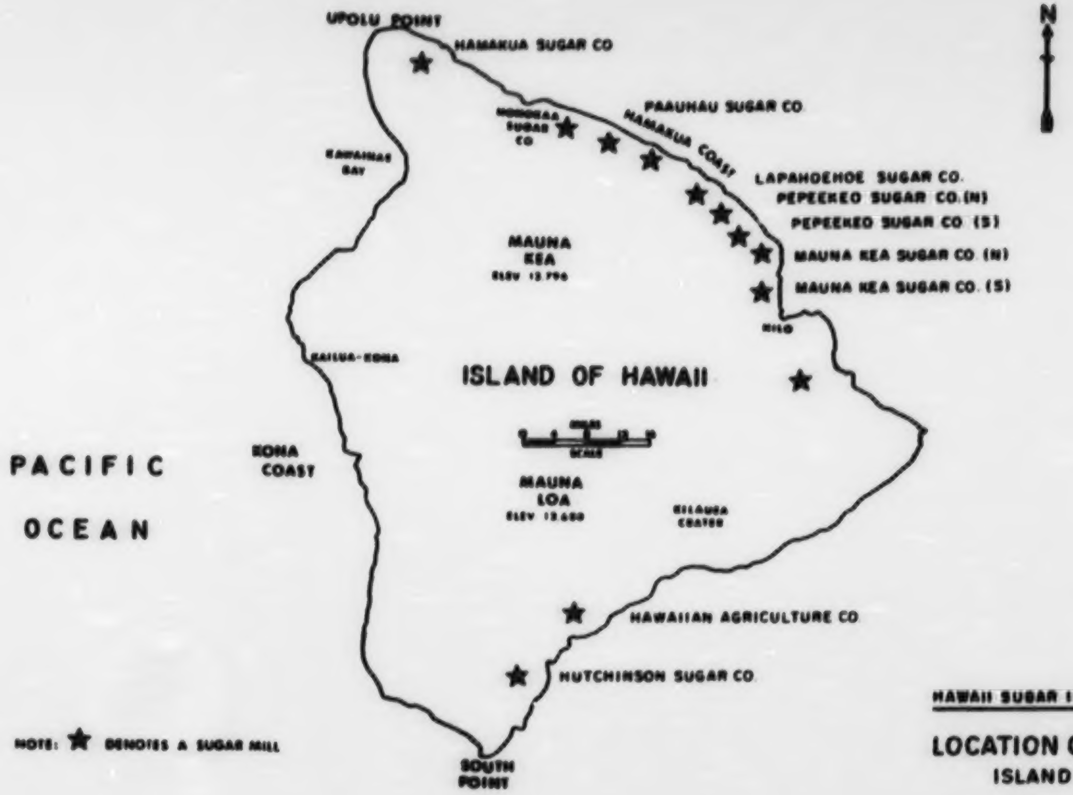
NOTE: ★ DENOTES A SUGAR MILL

HAWAII SUGAR INDUSTRY WASTE STUDY

LOCATION OF SUGAR MILLS
ISLAND OF MAUI

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

FIGURE 5


N
UPOLU POINT
HAMAKUA SUGAR CO
HONOKAA SUGAR CO
PAAUHAU SUGAR CO.
HAMAKUA COAST
LAPAHOEHOE SUGAR CO.
PEPEEKEO SUGAR CO.(N)
PEPEEKEO SUGAR CO (S)
MAUNA KEA SUGAR CO. (N)
MAUNA KEA SUGAR CO. (S)
HILO
KAWAIHAE BAY
MAUNA KEA ELEV 13,796
KAILUA-KONA
ISLAND OF HAWAII
MILES
SCALE
KONA COAST
MAUNA LOA ELEV 13,680
KILAUEA CRATER
PACIFIC OCEAN
HAWAIIAN AGRICULTURE CO
HUTCHINSON SUGAR CO
SOUTH POINT
NOTE: ★ DENOTES A SUGAR MILL

HAWAII SUGAR INDUSTRY WASTE STUDY

LOCATION OF SUGAR MILLS
ISLAND OF HAWAII

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

volcanoes, two are still active and two remain dormant.

Sugar is grown in three areas on the island of Hawaii. One is located inland approximately 10 miles south of the city of Hilo. Another area contains two sugar plantations and is located on the southeast quadrant of the island, generally south and west of Kilauea Volcano, near the southwest shoreline. The northern shore area, known as the Hamakua Coast, is the third and largest of these sugar-producing areas. Descriptions of land and water uses will be limited to the coastline areas.

The area between the northern tip of the island and Hilo consists primarily of agricultural, grazing, and undeveloped lands as well as the rugged Pololu-Waipio series of steep valleys. Except for small sandy beaches at the end of the valleys, the entire coast is essentially a solid chain of rugged sea cliffs. The area is quite scenic, however, and spectacular views are available from public lookouts. Nine sugar mills are located along this coastline.

From the area south of Hilo to Kilauea Volcano, the coastline is primarily bedrock, although a few beach areas are found. The area is essentially undeveloped, and several small shoreline parks have been proposed. Sugar is grown a few miles inland.

From Kilauea Volcano southwest to South Point, the coastline remains rugged, consisting mostly of bedrock and sea cliffs. With the exception of sugar production further inland, it is generally undeveloped and has only marginal access. Two shoreline parks have been proposed for this area.

IV. THE HAWAIIAN SUGAR CANE INDUSTRY

One of the earliest records of the existence of sugar cane in the Hawaiian Islands can be traced back to the arrival of Captain James Cook in 1778. Wild strains of sugar cane were noted to be present in the islands at that time. Between 1802 and 1835 various attempts were made to grow cane for sugar production; however, sizeable plantings did not flourish for any length of time. After 1836, more permanent cultivations began to appear. With demands for the product arising from the California gold rush of 1849 and the American Civil War of 1861, sugar became an important commodity for export.

The Reciprocity Treaty of 1875 allowed unrefined Hawaiian sugar to enter the United States duty-free and gave Hawaiian planters a two-cent-per-pound advantage over the other foreign sugar exporters. This price advantage provided the opportunity to develop marginal land, which had previously been uneconomical to cultivate. Today, as a result, Hawaii produces 1.2 million tons of raw sugar per year.

FIELD OPERATIONS

Planting: Sugar cane is first planted in soil which has been deep-plowed and formed into furrows that follow the contour of the land, thereby conserving rainfall and facilitating future irrigation. Short sections of plant stalk, containing one or more nodes. In about 24 months a mass of vegetation has developed, completely filling in the spaces between plants and rows and reaching a height of ten or more feet. When harvested, the root structure is left intact so that a second, third, or even fourth crop of sugar cane may be produced from suckers which grow from the root structure of old harvested plants. This process is known as "ratooning."

Weeding: Prior to World War II, handweeding to control weed growth was a common practice; however, rising labor costs forced cane growers to adopt herbicides. Today aerial applications of herbicides to supplement hand-spraying is practiced in Hawaii. Four applications per field crop may be necessary, with the heaviest applications during the first six months after planting.

Insecticides: Insects are not a serious problem in cane production, and no significant use of insecticides is made by the Hawaiian sugar industry.

Due to the heavy vegetative growth, however, extensive applications of fertilizers are necessary to maintain high cane yields. Average application rates, per acre, are 250 pounds of nitrogen, 150 pounds of phosphorus, and 230 pounds of potash. These applications can be carried out by hand, aerially, mechanically or through the irrigation water.

Harvesting: Prior to World War II, almost all cane was cut by hand and transported to the sugar mills through an extensive network of water flumes. When water flumes did not exist, mule-drawn wagons carried the cane to railroads for transport. This method of hand harvesting resulted, therefore, in a minimal movement of dirt and trash from the field to the mill.

Following World War II, mechanical harvesting completely replaced the hand cutting of cane. Conventional cane cutters have proven to be unsuccessful in Hawaii due to the thick cane blanket, rocky soil, and furrowed and hilly terrain. The most common method of harvesting is to snap off the cane at ground level with a bulldozer-type push rake that is mounted on a large standard tractor. Bulldozers then rake the cane into windows where crawler cranes, equipped with special grabs, load the windowed cane into special cane haulers usually consisting of an enormous truck-tractor unit and semi-trailer.

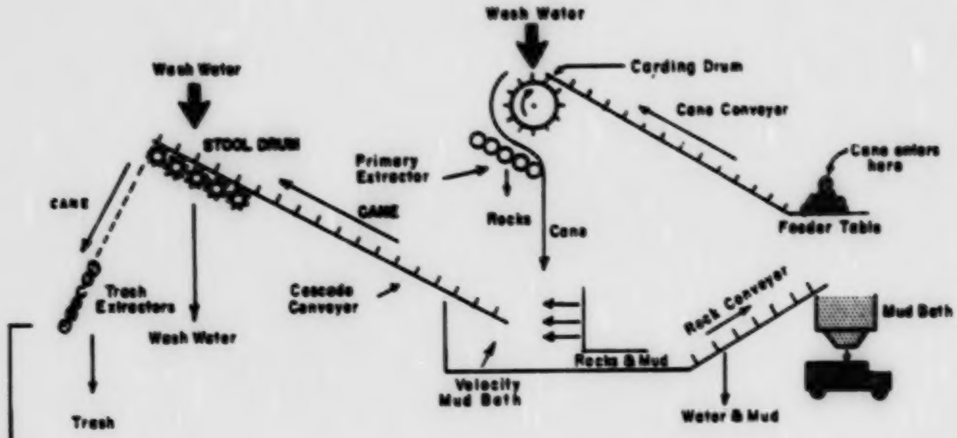
During the loading process, the harvesting grab and cane rake also uproot valuable top soil, roots, and rocks. This practice has necessitated the installation of cane washing systems at the sugar mills. A small percentage of the cane in Hawaii, however, is harvested by specially designed cutting knives which minimize the pickup of dirt and rocks.

FACTORY OPERATIONS

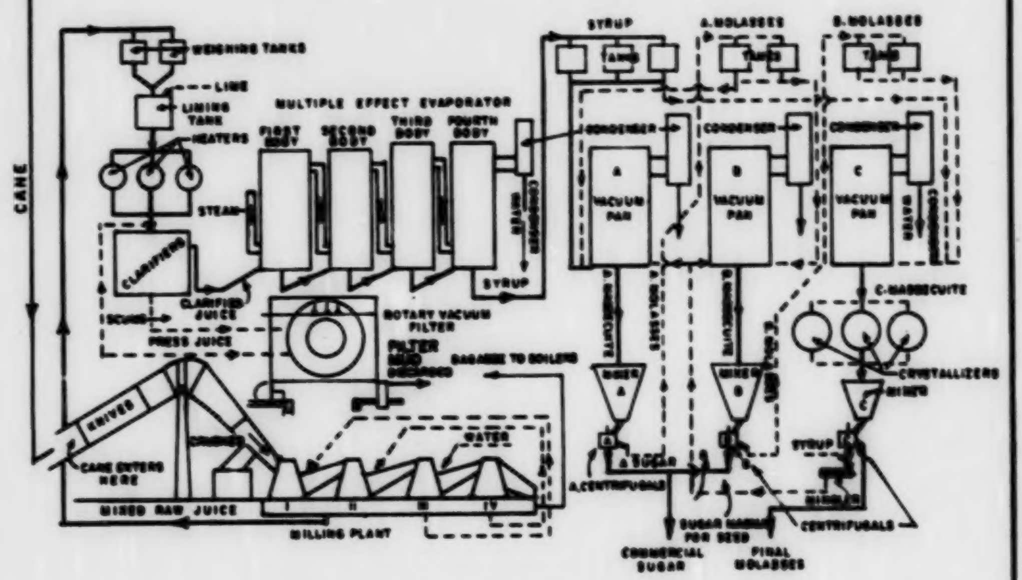
The typical sugar cane factory may be divided into three operating sections: (1) the cane preparation plant, (2) the milling plant, and (3) the boiling plant. Although no two factories in Hawaii operate identically, the prototype of what would be an average plant operation is described below and illustrated in Figure 6.

Cane Preparation Plant: The cane initially moves to a feeder table, up a conveyor, and then contacts a carding drum which spreads it out into a thin even blanket. Next it passes over a set of rollers which acts as a primary rock extractor. From there it falls into a flotation bath where rocks and other heavy foreign matter settle in the tank and are carried away.

FIGURE 6


Wash Water
Carding Drum
Cane Conveyor
Cane enters here
Feeder Table
Wash Water
STOOL DRUM
Primary Extractor
Rocks
Cane
CANE
CANE
Trash Extractors
Wash Water
Cascade Conveyor
Trash
Velocity Mud Bath
Rocks & Mud
Rock Conveyor
Mud Bath
Water & Mud

CANE PREPARATION PLANT


CANE
WEIGHING TANKS
LIME
LIMING TANK
HEATERS
MULTIPLE EFFECT EVAPORATOR
FIRST BODY
SECOND BODY
THIRD BODY
FOURTH BODY
STEAM
CLARIFIERS
SCUMS
CLARIFIED JUICE
PRESS JUICE
SYRUP
WATER
CONDENSER
ROTARY VACUUM FILTER
FILTER MUD DISCHARGED
BAGASSE TO BOILERS
KNIVES
CRUSHER
CANE ENTERS HERE
WATER
MIXED RAW JUICE
I
II
III
IV
MILLING PLANT
SYRUP
TANKS
A.MOLASSES
TANKS
B.MOLASSES
TANKS
CONDENSER
CONDENSER
CONDENSER
A VACUUM PAN
B VACUUM PAN
C VACUUM PAN
WATER
A MASSECUITE
A MOLASSES
B MASSECUITE
C-MASSECUITE
CRYSTALLIZERS
MIXER A
MIXER B
MIXER C
A SUGAR
A.CENTRIFUGALS
SYRUP
MINGLER
CENTRIFUGALS
SUGAR MAGMA FOR SEED
COMMERCIAL SUGAR
FINAL MOLASSES

MILLING AND BOILING PLANT

HAWAII SUGAR INDUSTRY WASTE STUDY

TYPICAL HAWAIIAN SUGAR MILL SCHEMATIC

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

Following the flotation bath, the cane proceeds up a cascade conveyor where heavy washing begins. Next it passes over stool drums to be shaken and leveled. The root structure holding the stalks together is then broken and here also final washing occurs. The cane then moves over trash extractors (oppositely spinning rollers) which grab and strip leaves from the stalks. The resulting trash is conveyed away from the cleaning plant. A series of knives then cut the cane into small lengths for crushing by a pair of corrugated rollers, the final preparation process preceding the roller mills.

Milling Plant: Each mill consists of a tandem of three rollers, and the chopped cane passes through each mill in succession to remove the cane juice. Either three, four, or five mills in a series are employed to squeeze the juice out of the cane stalks. After passing through the last mill, as much cane pulp (bagasse) as needed is fed into the mill fireroom for use as fuel. The remaining bagasse is either dumped into the ocean, used as landfill, or used to make compost.

Boiling Plant: Following extraction, sugar cane juice is weighed, limed, preheated, and sent through a clarifier to separate the supernatent. The sediment from the clarifier is run over vacuum filters and the extracted liquid is recycled to the clarifier. After leaving the clarifier, the juice enters a multi-effect steam evaporator from which it emerges with greater density as "syrup."

The syrup then enters vacuum pans where it is converted into molasses. In the pans, sugar crystals are also formed from the syrup by the process of evaporation to saturation. At the end of this operating cycle, the crystals are centrifuged to remove the molasses.

The sugar from the first pan operation is of commercial raw sugar quality and is ready for shipment to a mainland refinery. The molasses remaining from centrifuge of the first boiling operation is called "A" molasses. This is returned directly to the pans for a second cycle. The material from the second pan operation is centrifuged and the sugar produced is also of commercial quality. The molasses remaining from the second pan operation is called "B" molasses. "B" molasses is of low quality sugar content and must be specially processed before additional sugar can be produced.

WATER SUPPLY

Wide variations in precipitation occur throughout the

Hawaiian Islands. Areas with less than five inches of rainfall per year are found in some low lying canefields, while higher elevated fields may receive over 150 inches annually. Until 1875, sugar plantations in Hawaii were found only in areas of high rainfall. From then until 1910, however, the sugar interests vigorously pursued the development of irrigated canefields.

The volume of water consumed by all sources in the State of Hawaii totals 1,980 million gallons per day (mgd). Of this figure, 1,430 mgd is for crop irrigation (largely sugar cane) and 96 mgd is used for domestic purposes.

Stream diversion supplies the largest volume of water for sugar cane irrigation in Hawaii. The Koolau ditch of Maui which supplies 85 mgd exemplifies this type of water supply. It includes 7.5 miles of tunnels and 2.5 miles of ditches.

Ground water supplies the second largest source of irrigation water. The EWA Plantation on Oahu, for example, depends entirely for its water supply on more than fifty wells having a total capacity of over 120 mgd.

WASTE PRODUCTS DISPOSAL

Several waste products are produced by the sugar industry, and the methods of disposing of them vary from mill to mill. A general description of these wastes and their common method of disposal follows.

Wash Water: Millions of gallons of water per day are used to clean cane in the preparation plant. In some plants settling basins or hydroseparators are used after the washing process to settle and partially remove solids. After settling, the water may be either dumped to the sea or used for irrigation. However, a common practice on the Hamakua coast of the island of Hawaii is to flume the unsettled wash water directly to the sea.

Trash: The trash removed by extractors in the mill may be either dumped into the wash water for fluming to the sea, or removed by screening and then trucked away for use as landfill. In some cases, it is trucked to the shore, dumped, and carried out to sea by wave and current action. Some mills use an ensillage cutter to reduce the material to small pieces for use as mulch.

Bagasse: The pulp produced from the cane stalks after they pass through all the mills is called "bagasse." Bagasse is used to fuel the mill power houses and in some cases, excess amounts of it are flumed to the sea.

Ash: The ash which remains after the burning of bagasse is normally added to the wash water following cane washing. When solid clinker is produced, it is usually trucked away for landfill.

Condenser Water: Cooling water usually comes from the same supply as the wash water. The condensers used on the evaporators and vacuum pans are of the direct mixing type. The water emerging from the condensers may contain small quantities of sugar and other materials from the boiling process.

Filter Mud: Several tons per day of sediment come from the clarifiers after vacuum filtration. This combination of mud and fine fiber normally joins the wash water from the preparatory plant. Rocks removed from the flotation bath are usually trucked away and used for road construction or land fill.

V. WATER QUALITY STUDIES

Only meager data exist concerning the past and present water quality of the Hawaiian waters, particularly water quality in the vicinity of the sugar mill. These data can be grouped into studies by private consultants, generally oriented toward future placement of an outfall, and studies by various political or private entities concerning specific problem areas.

Selected reports containing data on relatively clean water or water under the influence of the sugar industry discharges will be presented. Reports concerning other problem areas such as pollution of harbors will not be included.[4]

GENERAL STUDIES

Data from surveys which have been conducted by private consultants often fail to provide sufficient information or to fully characterize a given study area within the island area. Frequently, studies consisted of a short series of grab samples taken at one or more stations; laboratory techniques were not adequately described; and research results were not reported in depth or in a manner convertible to customary engineering terminology. For example, many references were not explicit in making a distinction between total and soluble phosphorus or between phosphorus and phosphate.

The following summary of reports highlights the research studies which have been conducted on water quality in the Hawaiian Islands.

A three-day study was conducted in 1968 by Ultramar Laboratory on the waters off Honolulu International Airport. (1) Average values for two surface stations located approximately one mile offshore were:

Clarity: 23.1 feet

Temperature: 27.1° C.

D.O.: 5.60 mg/l

T.S.: 39.3 grams/l

pH: 8.22

---

[4] Numbers in parentheses refer to references noted in the Selected Bibliography of this report.

Organic Nitrogen: .08 mg/l

Soluble PO_4: 0.27 mg/l

Total Coliform: 1 organism/100 ml (MF)

Fecal Coliform: <1 organism/100 ml (MF)

In an earlier study (1965), Muroda and Tanaka sampled five sites off the western Maui coastline. (2) They obtained the following results:

pH: 8.41-8.45

BOD: 1.2-2.4 mg/l

T.S.: 33.8-41.6 grams/l

D.O.: 7.8-8.9

NO_3: <0.1-2.2 mg/l

PO_4: 0.1-0.3 mg/l

Chlorinity: 16.4-19.4 g/kg

Total Coliform: 0-6 organisms/100 ml (MF)

E. Coli.: 0 (MPN)

In 1964 Sunn, Low, Tom & Hara took samples near the shorelines of the west coast of Kauai. (3) The results of their study indicates:

pH: 8.02-8.15

NO_3-N: $<.01$-.01 mg/l

NH_3-N $<.02$ mg/l

Salinity: 32.3-39.4 0/00

Temperature: 25.9-26.5 C.

Total Coliform: 0-7000 organisms/100 ml (MPN)

In 1963 the firm conducted a similar study of the waters at a proposed outfall near Hilo, Hawaii. (4) Results indicated a pH of 7.6 and MPN total coliforms from 6 to 240 organisms/100 ml. An engineering study conducted by the firm in 1962 investigated a proposed outfall on the western side of Oahu.

(5) Included in the report were data gathered by the State Department of Land and Natural Resources in 1956-1958 from four stations along the coastline. The data summarized are as follows:

Temperature (surface): 22.9-27.2° C.

Temperature (bottom): 22.8-27.0° C.

Salinity: 34.6-34.8 0/00

PO_4 -P (surface): .009-.014 mg/l

PO_4 -P (bottom): .005-.0065 mg/l

Belt, Collins and Associates studied the location of a proposed outfall on the eastern coast of Oahu in 1959. (6) They found the following data for what was considered to be normal sea water:

pH (over a year's span): 7.90-8.11

DO (over a year's span): 4.2-7.6 mg/l

TS (over a year's span): 34.96-35.12 grams/l

PO_4 -P (3 samples): .0009-.0039 mg/l

Clarity: >35 feet

Routine water quality data gathered by State and county agencies generally are limited to bacteriological data from potable supplies and swimming areas. They, therefore, have little or no bearing on mill discharges. Six inshore stations were sampled, however, by the Maui County Department of Public Works (1965) along the west shore of Haleakala, Maui. (7) Results indicated:

pH: 8.15-8.25

Total Coliform: 0-15 organisms/100 ml (MPN)

Fecal Coliform: 0-9.1 organisms/100 ml (MPN)

In addition, the Hawaii Institute of Geophysics sampled Kaneohe Bay on September 7, 1962 and found the following information. (8)

Chlorinity: 19.12-19.49 0/00

O_2 Saturation: 81.8-89.8 percent

Total PO_4 -P: 0.009-.013 mg/l

A Masters thesis completed in 1968 at the University of Hawaii presented data on several chemical and physical parameters in Kaneohe Bay, Oahu. (9) The Bay is subject to stratification and is influenced by occasional large inflows of fresh water, as evidenced by divergent values which were recorded during the 13-month survey. Other findings indicated that mean total phosphate values ranged from .006 - .015 mg/l, with higher values at surface stations. During the survey extreme temperatures varied from 19.5° C. to 27.8° C., and similar variations were noted in salinity because of the fresh water inflow. Oxygen values ranged from 5-6 mg/l in the surf zones, to 3.5-4 mg/l near stream mouths.

STUDIES RELATED TO SUGAR INDUSTRY

Several reports have been written which have a bearing on the sugar industry and water quality, and these are summarized below.

The most recent study was conducted in 1966-1967 by a private consulting firm under contract to the Hawaiian Sugar Planters Association. The study consisted of both in-plant and offshore works, but has not been released to the public. (10)

At the public hearings on State water quality standards held in February 1967, a Sanitary Engineer and spokesman for the Hawaiian Sugar Planters Association presented an analytical summary of the wastes from ten sugar mills. (11) These analyses are prsented in Table 1.

In 1952, the Hawaii Board of Agriculture and Forestry conducted a survey of the coast of Maui in order to determine whether the industrial and agricultural wastes being drained into the ocean were in an amount or variety sufficient to kill fish. The report concluded that there were fewer fish in affected areas, but did not state that agricultural discharges were responsible. It also stated that the muds and particulate matter did not readily settle and that a major resulting damage was the destruction of sessile organisms (coral). Dissolved oxygen levels were recorded as saturated a short distance from the discharge points. (12)

At the request of local fishermen, the Board conducted a similar study along the south coast of Kauai in 1949. Its

TABLE 1 - SANITARY ANALYSES OF WASTEWATER DISCHARGES FROM TEN SUGAR FACTORIES

		CANE WASH WATER				COMBINED WASTE FLOWS			
	UNITS	NO.	MAX.	MIN.	AVG.	NO.	MAX.	MIN.	AVG.
Temp.	O C.	8	37.5	22.0	29.7	6	37.0	29.5	32.4
pH	Units	8	6.84	5.45	6.25	6	7.34	4.96	6.04
Turbidity	Units	8	7,350	283	2,056	6	5,450	300	2,198
Sett. Solids	ml/l	8	73	8.5	32	6	98	4.0	42
Susp. Solids	mg/l	8	17,390	1,627	7,436	6	25,375	1,320	7,908
BOD_5	mg/l	8	1,370	173	559	6	1,534	264	976
Chlorides	mg/l	4	27.0	7.5	13.6	6	950	10	171
PO_4 (as PO_4)	mg/l	4	< 0.2	<0.2	<0.2	6	<0.2	<0.1	<0.2
Org. N.	mg/l	4	25.0	2.0	14.1	6	105	5.0	27.2
NO_3 (as NO_3)	mg/l	4	1.3	<0.5	<0.7	6	1.3	0.4	<0.7
NO_2 (as NO_2)	mg/l	4	0.1	<0.1	<0.1	6	0.1	<0.1	<0.1

purpose was to determine the extent of pollution in the waters as influenced by the McBryde, Olokele, and Kekaha Mills and if possible, the effect of the pollutants upon inshore fisheries. No significant salinity changes were observed, but some areas of diminished oxygen were noted in the turbid water. Mud deposits were noted in some locations, but testing of the mud for hydrogen sulfide and arsenic proved negative. (13)

In 1947, the Territory of Hawaii conducted a study along the Hamakua coast of the island of Hawaii. The report contains a physical description of the area and lists complaints by local fishermen concerning the fouling effects of floating trash. The report concludes that trash is a nuisance, is deposited along the shoreline, and also settles to the bottom of the ocean. (14)

VI. MILL SURVEYS

The project focused on an in depth analysis of the three mills which were most representative of the 26 active sugar mills in Hawaii. The selection procedure consisted of choosing the three mills that would provide a maximum amount of data which could be projected validly to the remaining 23 mills.

Honokaa Mill: Eight mills exist on the windward, northeast (Hamakua) coast of the island of Hawaii. Similarities between these mills include locations along rugged inaccessible coasts, largely unirrigated cane fields, operations lasting ten to eleven months a year, agricultural and milling processes, soils, and little or no waste treatment.

The Honokaa Mill, one of these eight mills, was selected for the study for several reasons. (1) The lack of waste treatment in this area produces noticeable discoloration of the ocean from its waste discharges. Increasing controversy has occurred during recent years concerning the nature and effects of these discharges. (2) Since the survey included a study of the ocean adjacent to the mills it was necessary to select mill sites which had nearby and associated control areas. Waimanu Valley, a rugged undeveloped area which lies along the coastline adjacent to and northwest of Honokaa was selected as the control area for the Honokaa Mill.

Pioneer Mill: The island of Maui contains four sugar mills, and one of these -- Pioneer Mill -- was also chosen for the study. Located on the leeward side of the island, it has waste treatment in the form of settling ponds and a convenient nearby control area. The mill is also located in a rapidly expanding resort area and considerable concern has been voiced about the effects of mill discharge on present and future real estate and resort development.

McBryde Mill: Located on the northwestern island of Kauai is the McBryde sugar mill. This mill was selected because it had waste treatment in the form of a hydroseparator and also met the other established study criteria.[5]

---

[5] Hydroseparators are clarifiers consisting of circular excavations in the ground with mechanical sludge collection and steel overflow weirs.

GENERAL CHARACTERISTICS

Figures 7 through 13 and Tables 2 through 6 present the results of the three mill surveys which were conducted between July 1967 and March 1968. The figures give the average analytical results obtained for the study parameters, together with the average computed loadings. Data are presented for nutrient, solids, organic material, and bacteriological levels. Values are presented for the three survey mills in a left to right pattern that correlates with the flow pattern through the mills.

No values are given for the Honokaa Mill beyond the wash water stage, since it discharges this waste to the sea at this point. The Honokaa Mill is also unique in that solids from its rotary vacuum filters are not combined with other wash waters. Separate analyses were therefore conducted on both waste sources, and are presented individually in the analytical results. The loadings for the two sources, however, were combined under "wash water" in the loading figures.

Tables 2, 3, and 4 contain the values plotted in Figures 7 through 13. Table 5 presents the unit loadings (in pounds) of various wash water parameters per ton of raw sugar produced; these loadings were obtained from the average loading values presented in Table 4 and the average of the mill sugar production figures for the survey dates. Table 6 presents the results obtained from analysis of irrigation water.

Influent water for each of the three mills is obtained from different sources. (1) Honokaa Mill diverts the head waters of natural streams and channels them through flumes and tunnels to the Honokaa Mill reservoir, the vicinity of which is inhabited by wildlife. The water contains living and dead vegetation in addition to animal wastes and possibly man-made wastes. (2) McBryde Mill obtains its influent water primarily from the Hanapepe River which drains a large wilderness area of south-central Kauai. This water is stored in a small reservoir prior to entering the mill. Cows are frequently observed on land adjacent to the reservoir. (3) The Pioneer Mill obtains influent water from a ground water well located on the mill site. This water is brackish and may possibly be polluted from cesspools in the area.

Condenser processes in all three mills are similar. The Honokaa Mill discharges its condenser water to a cistern for peak flow storage. Large numbers of filamentous biological growth were observed in the cistern during the surveys. While some of the water stored in the cistern is recycled, most of it is combined with the waste stream which is discharged to the ocean. The cane washing process at all three mills is essentially the same, except at Honokaa Mill where mud from the rotary filters is not added to its wash water waste stream. In order to compare wash water from Honokaa with the other two mills it was therefore necessary to combine the mud from the Honokaa filter with its wash water results. These adjusted results are shown as loadings.

In their waste treatment processing of wash water, Pioneer and McBryde Mills subject their wash water wastes to an initial and secondary sedimentation process. At McBryde Mill the initial sedimentation is carried out in a circular clarifier basin with mechanical sludge collection. Initial sedimentation at Pioneer Mill is accomplished in either of two parallel settling ponds. One pond is allowed to fill with sediment and the flow is then switched to the alternate basin while the original pond is dredged. Settling efficiency is therefore dependent upon the length of time that a particular pond is in use.

At the McBryde Mill secondary sedimentation is accomplished by utilizing a large holding basin for the effluent from the primary clarifier. The basin stores the effluent during the afternoon and evening shifts for use as irrigation water during the morning shift. In the process of storage, sedimentation occurs in the basin. Because the basin is dredged annually, efficiency is dependent upon the time of year and the condition of the basin.

Pioneer Mill uses one of three settling basins at a time for secondary sedimentation, alternating their usage. The basins were designed for sediment removal, however, prior to the survey they had not been emptied for an extended period of time. As a result, the flow in the ponds at times was of a sufficient velocity to scour the sediment. The pond currently being used for operation, received water only during the afternoon and evening shifts and was generally stagnant during the day. It is questionable whether this pond was beneficial, and as subsequent results may show, it may even have altered the wastes in a negative manner.

The average flow rates at the three mills were between 5 and 10 mgd. This is a typical flow for most mills in the State.

BACTERIOLOGICAL RESULTS

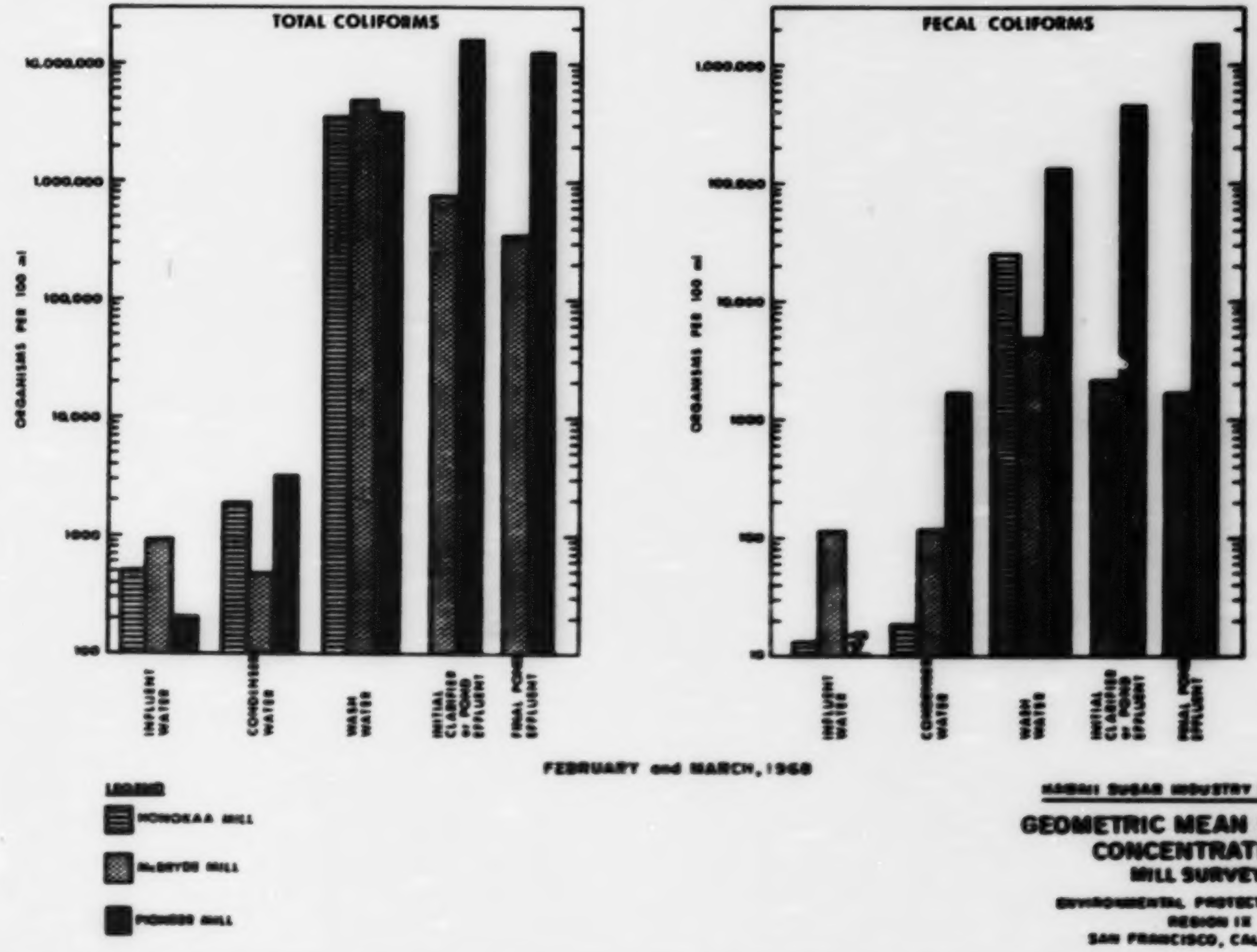
Geometric mean values for total and fecal coliform levels, shown in Figure 7 and Table 2, give the results of the third and final series of mill surveys which were conducted in February and March, 1968. Similar tests were conducted on composite samples in the previous two surveys. It was subsequently established, however, that the coliform organisms were multiplying in the composite containers, and it was decided to disregard the bacteriological results of the first two surveys and conduct a grab sampling program using improved techniques. In the spring survey, tests were run, using the Millipore Filter method, within 60 minutes of the sampling time.

The total coliform group of bacteria occurs in sanitary sewage, in the intestinal tracts of animals, and also in relatively harmless habitat such as soil. With few exceptions the total coliform group is not harmful and has been used by regulatory agencies for many decades as an indicator of pathogenic organisms because total coliform and pathogenic organisms usually exist concommitantly. The fecal coliform group of bacteria is almost exclusively derived from the intestinal tracts of warm-blooded animals and is therefore a more reliable indicator of the presence of intestinal pathogens.

The water supply for the Honokaa and McBryde Mills had total coliform geometric means between 500 and 1,000 organisms per 100 milliliters. Fecal coliform maximum values were 60 and 200 organisms per 100 milliliters for the Honokaa and McBryde water supplies, respectively. The Honokaa water is also used for domestic purposes in the village of Haina. The Pioneer Mill water supply had a geometric mean for total coliforms of 206/100 ml and values for all fecal coliforms of less than 10/100 ml. The initial bacteriological quality of the water supplies of both the Honokaa and McBryde Mills approach the upper limits permitted by the Hawaii Water Quality Standards for fresh water.

Condenser Water: No significant changes occurred in bacterial densities between the influent and condenser sampling points at either the Honokaa or McBryde Mills. Pioneer Mill, however, exhibited more than a tenfold increase in fecal coliforms. No definite explanation was found for this increase at Pioneer Mill, or why the same increase did not occur at the other two mills. Similar increases, however, have been noted previously in other industries such as beet sugar, and paper production where warm temperatures and nutrients promote biological growth during the manufacturing process.

FIGURE 7



HAWAII SUGAR INDUSTRY WASTE STUDY

GEOMETRIC MEAN COLIFORM CONCENTRATIONS
MILL SURVEYS

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

TABLE 2 - GEOMETRIC MEAN COLIFORM CONCENTRATIONS, MILL SURVEY (Organisms/100 ml)*

Location	Total No. of Samples	Total Coliforms	Fecal Coliforms
HONOKAA MILL			
Influent	9	512	12
Condenser	9	1,880	18
Washwater	10	3,350,000	24,100
McBRYDE MILL			
Influent	4	905	116
Condenser	4	475	126
Washwater	5	4,850,000	4,880
Clarifier Effluent	3	735,000	2,010
Final Pond Effluent	3	338,000	1,630
PIONEER MILL			
Influent	3	206	<10
Condenser	3	3,280	1,710
Washwater	4	3,900,000	130,000
Initial Pond Effluent	3	15,100,000	468,000
Final Pond Effluent	3	13,500,000	1,610,000

* February - March, 1968.

Wash Water: Large increases in total coliform densities occurred in the water of all three mills after passage through the washing plant. Large increases in the fecal coliform parameters were also observed: values for the Honokaa Mill increased by a thousandfold, the McBryde Mill by fortyfold, and Pioneer Mill by seventy-fivefold. The condenser water in all cases was sampled immediately before entering the cane washer. The increase in coliform count is attributed to the soil particles and other material washed from the cane. No attempt was made to determine the sources of the fecal coliform bacteria although suspects include rats, mongooses, and other animals that inhabit the fields.

Primary Clarifier or Pond Effluent: Total coliform and fecal coliform values were reduced by more than 50 per cent at the McBryde Mill after the water had passed through the mechanical clarifier (hydroseparator). In contract, total coliform and fecal coliform values increased at Pioneer Mill after initial sedimentation.

Since significant removal of solids and other parameters occurred in the primary sedimentation ponds at Pioneer Mill, the increase in total coliform values was presumably due to multiplication of the bacteria. Wash water samples at Pioneer Mill were taken at the point where the wash water enters the primary settling pond, while the effluent samples from the primary pond were taken at the influent point of the secondary pond, which is located approximately three miles from the primary pond. Bacteriological regrowth could therefore take place during the passage through the three-mile ditch connecting the two ponds.

It is theorized that reasons for the lack of regrowth in the McBryde clarifier may be related to the time factor or lack of a significant sludge interface at the bottom of the clarifier.

Secondary Pond Effluent: Additional bacteriological reductions occurred for both total and fecal coliforms following retention of effluent in and passage through the McBryde secondary basin. Conversely, the fecal coliform values continued to rise in the secondary pond at Pioneer Mill while the total coliform values indicated a slight decrease.

The adverse changes in the Pioneer Mill samples may be due to continued regrowth, scouring, or a combination of these two processes. Increases in several other parameters were also noted, particularly solids following passage through the Pioneer secondary ponds during the spring survey period. All these increases may be due to the scouring of bacteria-laden particles from the channels. It is noteworthy that despite overnight detention in the McBryde pond, no evidence of coliform regrowth was apparent.

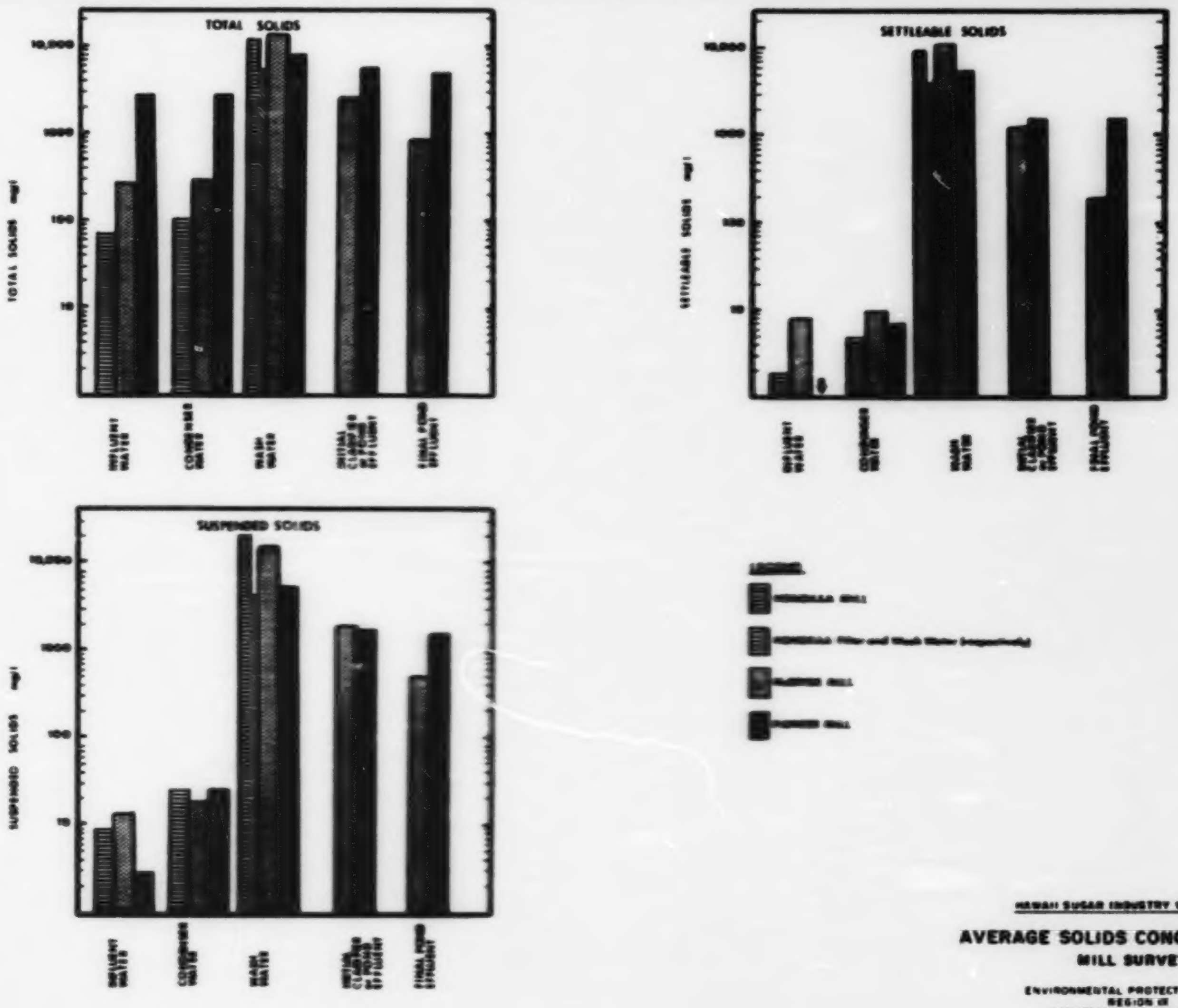
Significance of Bacteriological Results: Extremely high densities of both total coliforms and fecal coliforms are present in the final effluent from mill wastes regardless of whether or not these wastes had undergone sedimentation. Wherever total coliforms and particularly fecal coliforms are present in waters in the high concentrations indicated, the water must be labeled as being a potential source of dangerous pathogenic organisms. This is true not only because of the high densities present, but also because it is possible that conditions in the waste which allow the apparent regrowth of the indicated organisms may also cause the regrowth of pathogens.

SOLIDS RESULTS

Average solids concentration and loadings for all three surveys are shown in Figures 8 and 9 and Tables 3 and 4. Total solids values represent solids in suspension and solution. It should be noted that total solids concentration does not necessarily indicate a turbid sample. This fact is exemplified by the sea water surrounding Hawaii which is crystal clear yet has a very high total solids concentration due to its total amount of dissolved salts.

Suspended solids analyses indicate those particles which are suspended in water, generally impart turbidity, and are removed by fine filtration. Settleable solids represent the amount of solids present on a weight basis, that settle to the bottom of a still container after a definite period of quiescence. In this study, that time period was one hour.

Influent Water: Solids concentration and loadings of influent water were of a low or insignificant level in the water supply at the Honokaa and McBryde Mills. Due to the brackish nature of the ground water source, the Pioneer Mill water supply contained high levels of dissolved solids. This water was, however, low in suspended solids and virtually void of all settleable solids due to natural filtration of the soil media. The water supply at McBryde Mill contained small but measurable amounts of suspended and settleable solids presumably composed of river sediment and macroscopic plant life. Honokaa Mill also contained similar quantities of such solids, although the greatest postion of these appeared to be algal growths.



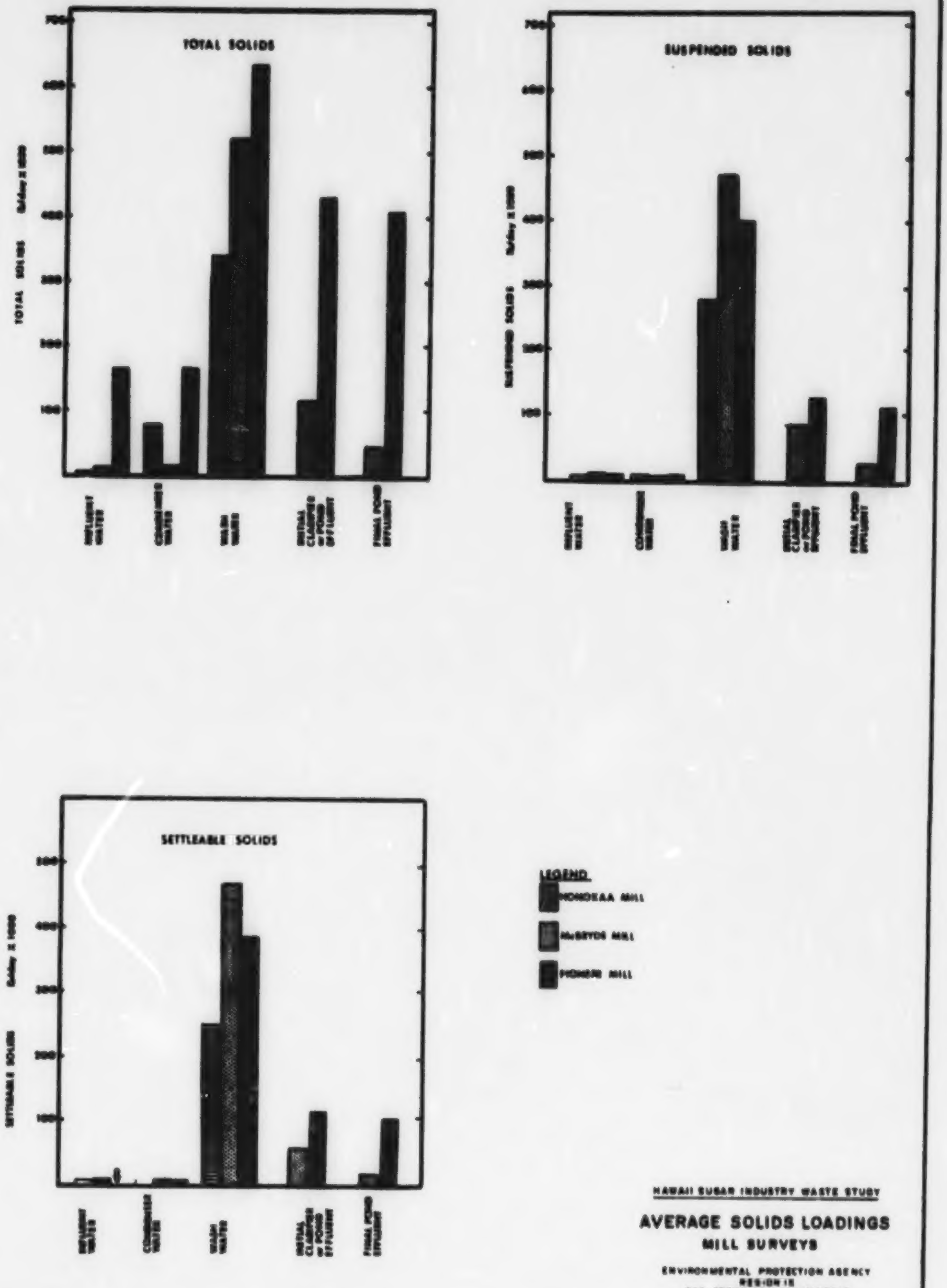
HAWAII SUGAR INDUSTRY WASTE STUDY

AVERAGE SOLIDS CONCENTRATIONS
MILL SURVEYS

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

FIGURE 8

FIGURE 9



HAWAII SUGAR INDUSTRY WASTE STUDY

AVERAGE SOLIDS LOADINGS
MILL SURVEYS

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

TABLE 3 - AVERAGE CONCENTRATIONS, MILL SURVEYS (mg/1)*

	ANALYSES:							
Location	Total Solids	Suspended Solids	Settleable Solids	Biochemical Oxygen Demand	Chemical Oxygen Demand	Total Organic Carbon	Total Nitrogen (N)	Total Phosphorus (P)
HONOKAA MILL								
Influent	68	9	2	10	16	11	0.4	0.07
Condenser	100	24	5	45	93	36	0.7	0.07
Washwater	5,700	4,500	4,050	795	2,700	545	51.0	23.0
McBRYDE MILL								
Influent	250	13	8	8	6	4	0.4	0.03
Condenser	30	20	10	14	42	13	0.6	0.15
Washwater	12,000	10,700	10,500	800	2,300	710	44.	13.
Clarifier Eff.	2,650	2,000	1,160	655	900	330	9.1	5.8
Final Pond Eff.	950	530	170	500	600	190	4.8	1.5
PIONEER MILL								
Influent	2,800	3	0	-	34	4	0.2	0.08
Condenser	2,700	24	7	70	110	19	1.6	0.41
Washwater	8,700	5,500	5,300	670	1,100	420	23.	8.5
Initial Pond Eff.	5,900	1,700	1,500	520	690	230	11.	4.7
Final Pond Eff.	5,600	1,600	1,400	425	755	150	14.	3.6

* Results of 3 Surveys Conducted between July 1967 - March 1968.

TABLE 4 - AVERAGE LOADING, MILL SURVEYS (pounds/day)*

Location	Total Solids	Suspended Solids	Settleable Solids	Biochemical Oxygen Demand	Chemical Oxygen Demand	Total Organic Carbon	Total Nitrogen (N)	Total Phosphorus (P)
HONOKAA MILL								
Influent	5,100	660	240	730	1,200	830	31	5
Condenser	75,000	1,950	365	3,750	6,700	2,700	51	4
Washwater	340,000	280,000	245,000	58,000	178,000	39,000	3,400	1,600
McBRYDE MILL								
Influent	10,900	580	360	320	290	150	19	1
Condenser	13,000	880	450	630	1,900	580	26	7
Washwater	520,000	470,000	470,000	35,000	99,500	31,000	1,900	565
Clarifier Eff.	115,000	85,000	49,000	29,000	39,000	14,000	400	250
Final Pond Eff.	43,000	24,000	7,600	21,333	27,000	8,600	225	69
PIONEER MILL								
Influent	165,000	190	Negligible	-	2,000	280	23	5
Condenser	160,000	1,600	500	5,000	6,900	1,300	125	29
Washwater	636,000	400,000	380,000	49,500	82,000	30,000	1,700	620
Initial Pond Eff.	431,000	127,000	112,000	38,500	52,000	18,000	800	340
Final Pond Eff.	410,000	115,000	102,000	31,500	56,000	11,000	1,050	260

* Results of 3 Surveys Conducted between July 1967 - March 1968.

Condenser Water: Only minor amounts of additional solids were added between the influent and condenser sampling points. This change can be attributed to minor losses of sugar at all mills, and at the Honokaa Mill some biological growth in the cistern also contributes to this increase.

Wash Water: Average solids values rose markedly in all mills by factors of approximately 180 to 500 after the wash water passed through the cane washing plant. The rise in total solids values was directly related to changes in the suspended solids values, indicating that suspension of soil and other particles from the cane was largely responsible for the rise, rather than actual solution of any sugars.

The most striking and significant relationship shown in Figures 8 and 9 is the high percentage of settleable solids contained in the suspended material. In all cases, more than 90 per cent of the suspended solids were of a settleable nature. This was further verified by the high removal percentages.

A true perspective of the loadings can be found in Table 5 which gives the unit wash-water loadings based on tons of raw sugar produced. For the total solids parameter, the figures are about equal, with the McBryde Mill having a slightly higher value. Pioneer Mill, however, had a high total solids content in its influent water and, assuming proper adjustment, would therefore have a considerably lower unit loading. For suspended and settleable solids, McBryde Mill had the highest unit loadings, while Pioneer Mill had the lowest figures.

Factors that affect the quantity of total solids contained in the wash water are the efficiency of the cleaning plant, the moisture condition of the fields, harvesting procedures and cane quality. The only significant rainfall which occurred was during the spring surveys at two of the mills, and in both instances the plants shut down when the effects of the rain began to interfere with harvesting operations. It is believed that the principal factor contributing to lower unit values at the Pioneer Mill is the use of an overhead grab machine for harvesting the cane. McBryde and Honokaa Mills use the more common "push rake" which plows the cane into piles and picks up much greater quantities of rocks and dirt in the process. The differences between the Honokaa and McBryde values are more difficult to explain. These may be due to cleaning plant efficiencies as well as coarse soil at the Honokaa plantation.

Primary Clarifier or Pond Effluent: Significant amounts of sediment were removed in the initial sedimentation processes at both Pioneer and more particularly McBryde Mill. Annual averages indicate approximately 70 per cent removal of suspended and settleable solids at Pioneer Mill, with between 80 and 90 per cent removal of suspended solids at the McBryde Mill.

Secondary Pond Effluent: Since secondary ponds at Pioneer Mill required dredging, the samples of water taken there were of dubious value. The average values of sediment removed from Pioneer Mill secondary ponds indicated a slight additional removal; however, during the spring survey, solids values were actually higher in the effluent than in the influent. The McBryde Mill removed additional solids from the primary effluent and thereby achieved significant reduction in total solids. Overall removals at McBryde Mill totaled 95 per cent for suspended solids and were greater than 98 per cent for settleable solids.

Significance of Solids: The most striking characteristics of the solids data are (1) the high proportion of settleable solids in the wash water, and (2) the amenability of the wastes to solids removal through basic sedimentation processes. The 95-98 per cent removals of suspended and settleable solids at the McBryde Mill, without the use of any coagulants, and with only a minimum of maintenance is excellent.

Results from several particle size tests indicate that the size of solids particles fall within the silt and clay particle size distribution range, and theoretically should not exhibit this high degree of settleability. The most probable reason for this phenomenon is the attraction of particles to one another to form a floc which then tends to sweep other particles to the bottom.

It appears, therefore, with properly designed equipment, the assignment of responsibility, and with adequate automated or intermittent sludge disposal, the 95-98 per cent removals of settleable solids achieved at the McBryde Mill can be obtained at all mills without the use of coagulants. Even after such a high sediment removal, however, the water at the McBryde Mill produces a turbid effluent. The remaining 5 per cent of unremoved material represents several thousand pounds of solids discharged per day. The addition of a moderate amount of coagulants is likely to remove most of the remaining suspended solids.

As indicated by the Pioneer Mill unit loading data, another significant finding is the potential reduction of solids through the use of overhead harvesting grabs. The Pioneer equipment was designed to minimize the number of rocks that are unintentionally removed from the fields and brought to the mill cleaning plant. The equipment also tends to reduce the quantity of soil particles which normally cling to the cane during the harvesting process.

ORGANIC RESULTS

Three types of analyses were conducted on the wastes of the mills to indicate organic material. These were biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total organic carbon (TOC). Results of these analyses are summarized in Figures 10 and 11 and Tables 3 and 4.

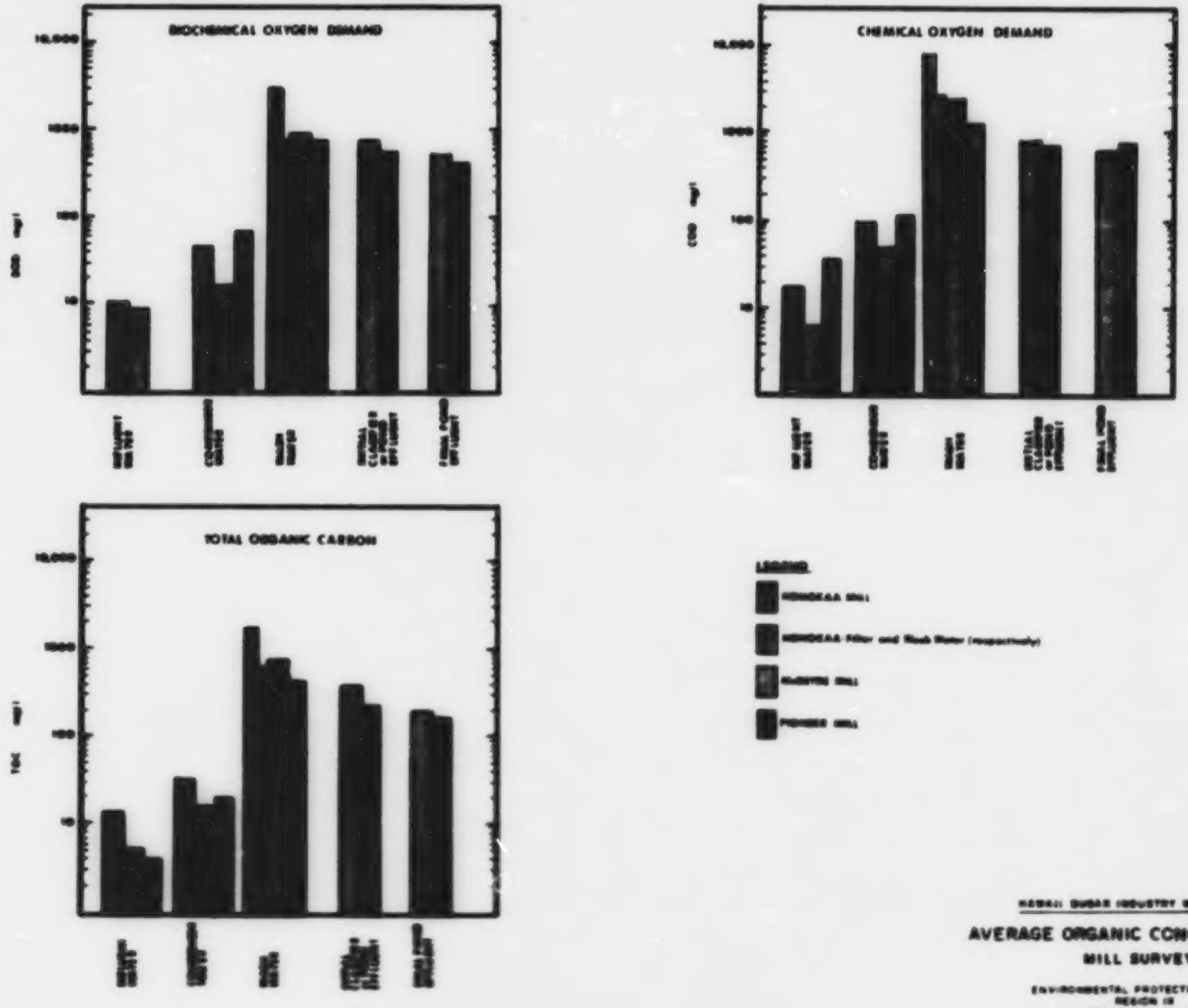
The BOD test indicates the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic (oxygen-present) conditions for a specified time interval. The COD test makes a similar determination but more nearly represents total oxidation requirements. The latter uses strong chemicals rather than living bacteriological organisms to break down the organic matter. The TOC test measures the amount of organic carbon present in a water sample. It does not measure inorganic carbon compounds such as carbon dioxide or the carbonates.

Influent Water: It should be noted that because of insufficient data, BOD values are not presented in the figures for Pioneer Mill.

Values for BOD, COD, and TOC parameters are generally low as would be expected from the water sources. The possible exception occurs at Pioneer Mill, where a COD value of 34 mg/l (2,000 lbs/day) seems excessive.

Condenser Water: All three parameters showed increased values between the influent and condenser stages. This rise is attributable to the possible introduction of some sugars into the water as well as to biological growths during storage of the water.

Wash Water: All values for BOD, COD, and TOC rose markedly after the wash waters had passed through the washing plant. BOD values increased from tenfold at Pioneer Mill to more than fiftyfold at McBryde Mill. COD values followed similar patterns, while total organic carbon increased by factors of 15, 22, and 55 at Honokaa, Pioneer, and McBryde Mills, respectively. Table 5 shows that unit



HAWAII SUGAR INDUSTRY WASTE STUDY

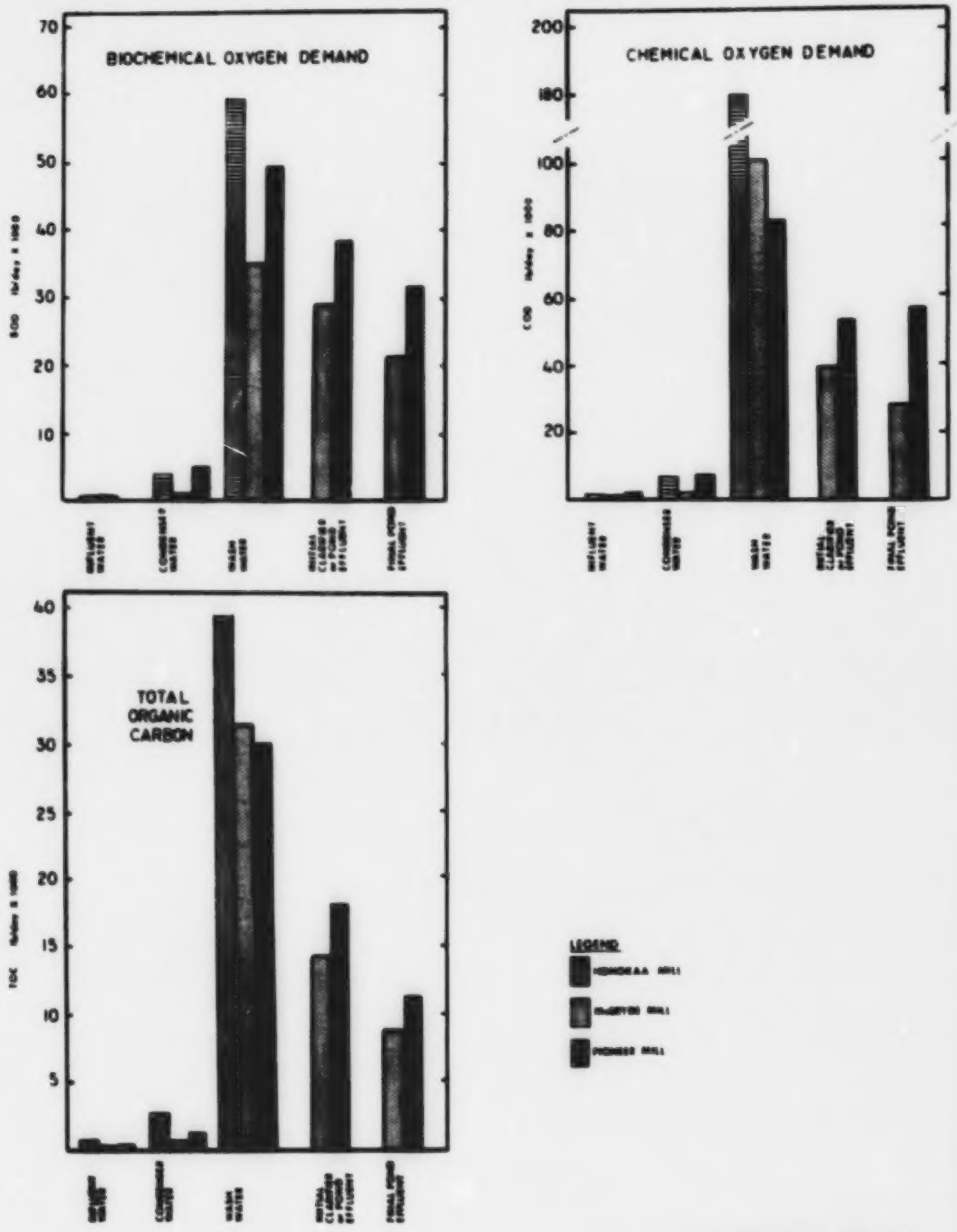
AVERAGE ORGANIC CONCENTRATIONS

MILL SURVEYS

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

FIGURE 10

FIGURE 11



HAWAII SUGAR INDUSTRY WASTE STUDY

AVERAGE ORGANIC LOADINGS
MILL SURVEYS

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

TABLE 5-AVERAGE UNIT WASTE LOADINGS FROM SURVEY MILLS-WASH WATER(lbs/ton of raw sugar produced)*

Mills	Total Solids	Suspended Solids	Settleable Solids	Biochemical Oxygen Demand	Chemical Oxygen Demand	Total Organic Carbon	Nitrogen (AsN)	Phosphorus (AsP)
HONOKAA	2,300	1,800	1,600	390	1,150	250	22	10
McBRYDE	2,500	2,300	2,300	170	490	150	9	3
PIONEER	2,300	1,450	1,400	180	300	110	6	2

* Results of 3 Surveys Conducted between July 1967 - March 1968.

loadings for the three parameters are approximately equal for McBryde and Pioneer Mills but about twice as high for Honokaa Mill. Perhaps this can be attributed to the fact that Honokaa Mill makes no effort to remove foliage and waste fibers (trash) from the wash water as do the other mills before the water enters the settling basins.

Primary Clarifier or Pond Effluent: In the initial sedimentation processes, the OBD removals averaged about 20 per cent at both McBryde and Pioneer Mills. COD removal was considerably higher, however, with about 35 per cent removal at Pioneer Mill and 60 per cent removal at McBryde Mill. Total organic carbon reductions at both mills amounted to about 45 per cent.

Secondary Pond Effluents: Reductions in BOD, COD, and TOC parameters occurred in the secondary pond at McBryde Mill. Average overall reductions in both mill basins amounted to 35 per cent for BOD, 74 per cent for COD, and 73 per cent for total organic carbon. Average detention time in the final reservoir at McBryde exceeded 24 hours; and because of this longer detention time biological decomposition of organic matter probably had a more significant effect in this basin. Biological decomposition is further indicated by the penetrating odor occasionally emitted from this pond.

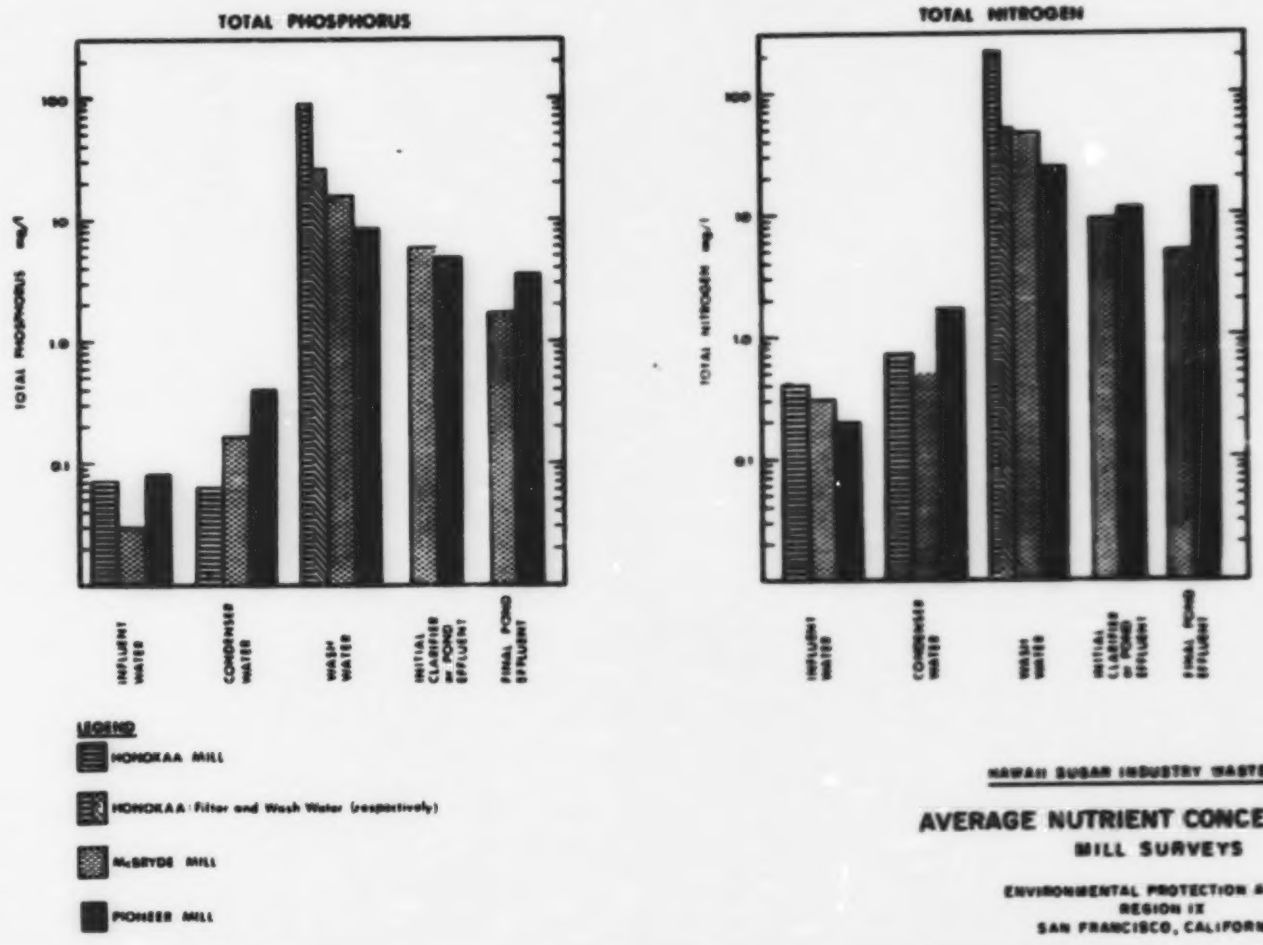
Reductions of BOD and TOC parameters occurred in the Pioneer Mill secondary ponds and an insignificant rise in COD values also occurred. Because of the relatively high velocity of the flow in the basins, these reductions were undoubtedly due to biological decomposition rather than settlement. Overall reductions at Pioneer Mill were 35 per cent for BOD, 30 per cent for COD, and 65 per cent for total organic carbon.

Significance of Organic Results: BOD, COD, and TOC can be used to indicate the susceptibility of wastes to eventual decomposition and also to determine their subsequent demand on the oxygen resources of receiving waters. Even after significant removals through treatment processes, results show that when wastes are discharged into coastal bays or other areas of limited circulation, they are still capable of exerting an oxygen depletion.

NUTRIENT RESULTS

Average annual results for total nitrogen, N, and total phosphorus, P, are presented in Figures 12 and 13 and Tables 3 and 4.

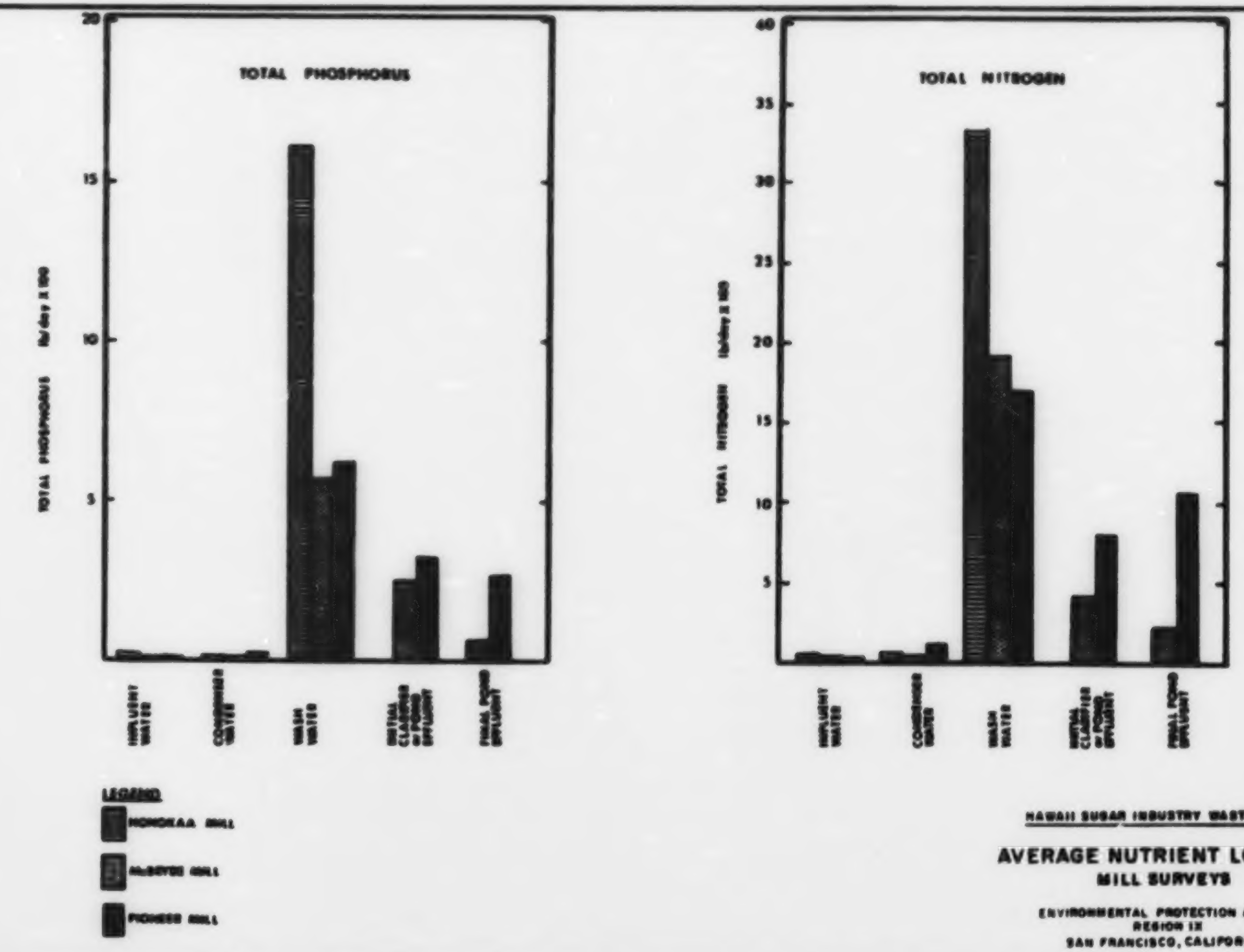
FIGURE 12



HAWAII SUGAR INDUSTRY WASTE STUDY

AVERAGE NUTRIENT CONCENTRATIONS
MILL SURVEYS

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA



HAWAII SUGAR INDUSTRY WASTE STUDY

AVERAGE NUTRIENT LOADINGS
MILL SURVEYS

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

FIGURE 13

Influent Water: As would be expected for waters from these sources, nitrogen and phosphorus values were generally in the range of average quality. Total phosphorus values were less than .1 mg/l, and total nitrogen values were less than .5 mg/l.

Condenser Water: Increases in nutrients were observed in the condenser water, however, the amount was still insignificant, as indicated by the loading values in Figure 13 and Table 4.

Wash Water: Like previous parameters, values for the nutrient parameters also increased sharply after passage of wash water through the cane washing plants. Phosphorus and nitrogen values increased by factors of 75 and 300, respectively, at Honokaa Mill, and 85 and 70 at McBryde Mill, and 20 and 14 at Pioneer Mill.

Orthophosphates formed less than one per cent of the total amount of phosphorus, This finding would indicate that the source of phosphorus is primarily organic in the fibrous plant material, or the more insoluble forms of phosphorus such as calcium phosphate which adheres to the soil particles.

Total nitrogen values were primarily of an organic nature with ammonia, nitrate, and nitrite nitrogen forming less than 10 per cent of the total amount. Most of the nitrogen comes from the cane fibers and other materials of the cane itself.

Table 5 shows that the Honokaa Mill again had significantly higher unit loadings than the other two mills. This fact is primarily attributed to the fibrous cane material (trash) which Honokaa does not remove from its waste stream. The moist climate of the Honokaa area also results in a higher volume of incoming trash than is found at Pioneer or McBryde Mills.

Primary Clarifier or Pond Effluent: Significant nutrient removals were observed at both McBryde and Pioneer Mills following passage through the initial clarifiers. The largest reductions occurred at the McBryde Mill through the use of the automated hydroseparator. It is believed that screening of trash prior to entry in the hydroseparator and continuous mechanical sludge removal account for the superior performance at this mill.

Secondary Pond Effluent: Further reductions in total nitrogen and total phosphorus continued in the secondary pond at McBryde Mill. Overall reductions for both basins at the mill averaged between 85 and 90 per cent for both parameters.

A reduction in phosphorus content occurred at the Pioneer Mill secondary pond while a noticeable increase occurred in the nitrogen values. This rise in annual averages resulted from a major increase in nitrogen during the spring survey, when visual observations indicated that significant erosion in pond deposits was occurring. Some reduction in nitrogen values was evident in the previous two surveys.

Significance of Nutrient Results: Nitrogen and phosphorus are known contributors to eutrophication or excessive growth of undersirable algae and other aquatic plant life. The mill wastes are strong enough to produce these ecological changes if discharged to confined receiving waters. Many of the mills in the State have outfalls which discharge into open bodies of water where ocean currents disperse the effluent and sweep it away. On the other hand, several mills discharge wastes into bays or other coastal areas with limited circulation.

ARSENIC, HERBICIDES, AND pH RESULTS

Prior to synthesis of modern herbicides, the Hawaiian plantations added extensive quantities of arsenic to the soils for control of undesirable plant life. Analyses were run on many of the mill samples to determine if arsenic still existed in the soil particles of the wash water. Significant concentrations were found in the wash waters of the Honokaa Mill. An average of 1.4 mg/l was found in the mill's filter discharge even though the volume of this discharge was relatively small, whereas in the wash water, a much larger volume, results indicated averages as high as 0.5 mg/l. Arsenic was also found in the McBryde Mill wash water although at much lower concentrations. It was not found in noticeable quantities at the Pioneer Mill.

Since the preliminary investigation of each mill covered in detail the quantities and procedures of usage of pesticides, only a cursory study was conducted to determine the occurrences of herbicides in the actual mill wastes. Gas chromatograph analyses were conducted for two of the chemicals commonly used by the sugar industry; 2,4,5T and Atrazine. Only negligible amounts were found of 2,4,5T; and of Atrazine, the highest concentration found was 9.25 micrograms per liter.

Other herbicides used by the Hawaiian plantations include Ametryne, Dowpon, and Karmex (also known as DCMV or Diuron). Tests were not conducted to detect their presence.

This study was neither planned nor equiped to realistically evaluate the effects of herbicides on the receiving water and its biota. These parameters merit further investigation as indicated by the limited tests which were conducted and the testimony given during public hearings which preceded the adoption of water quality standards in which it was proported that subtle and long-range damage had occurred to the shoreline fishery.

The pH of the mill wash waters was lower than the influent water by one unit. This fact can be attributed to the natural pH of the cane juices, as well as to the possible formation of acid following bacteriological breakdown of the organic matter.

Further pH reductions were noted at McBryde Mill after wash waters passed through the two sedimentation basins. This fact could be attributed to the previously mentioned biological breakdown and subsequent formation of organic acids. Discharges of wastes from the final sedimentation process to the ocean cause no significant pH problems in the ocean because of the near neutral pH levels and high buffering characteristic of sea water.

IRRIGATION WATER RESULTS

The concentrations and levels of polluting parameters in excess irrigation water (tailwater) can in some instances equal or exceed the mill wastes. In the majority of cases, however, if the discharge volume is not excessive, the total effects of the wastes would be less than the actual mill wash water. The possible exception to this situation would be nitrates because tailwater values exceed average mill wash-water values in all but one case. Results of these findings appear in Table 6.

TABLE 6-ANALYTICAL RESULTS, EXCESS IRRIGATION WATER (TAILWATER) FROM McBRYDE PLANTATION

INFORMATION	FIELD NUMBER				
	13A	8B	9A	12	5B
Date Planted	5/66	7/67	8/67	11/67	3/66
Date Sampled	11/1/67	3/27/68	3/27/68	3/27/68	3/28/68
Total Solids mg/l	574	204	92	900	3390
Suspended Solids mg/l	248	112	40	584	3230
Settleable Solids mg/l	174	106	34	288	2280
COD mg/l	37	14	<1	55	347
Total Organic Carbon mg/l	15	5	5	22	91
Ammonia Nitrogen mg/l (As N)	0.1	0.01	0.04	0.49	5.3
Nitrite Nitrogen mg/l (As N)	0.065	0.01	0.005	0.016	0.002
Nitrite Nitrogen mg/l (As N)	0.165	0.438	0.106	0.29	0.29
Kjeldahl Nitrogen mg/l (As N)	0.5	0.7	1.	13.9	34
Total Phosphorus mg/l (As P)	-	0.37	0.17	1.7	25.1
Ortho Phosphorus mg/l (As P)	0.05	0.092	0.008	0.01	0.043
Arsenic ug/l	-	<10	<10	<10	<30
pH Units	7.3	7.2	6.9	6.7	6.6
Total Coliform/100 ml	-	13,000	500	<1,000	250,000
Fecal Coliform/100 ml	-	1,300	70	1,300	7,000

VII. OFFSHORE SURVEYS

GENERAL CHARACTERISTICS

Offshore surveys were conducted for four sugar mills (Honokaa, Pioneer, McBryde, and Olokele) to evaluate the effects of mill waste on various water usages in the coastal receiving waters.[6] The following parameters of water usage were investigated: aesthetic effects, water contact sports, and propagation and sustenance of marine life (shellfish, fauna, and coral). The following physical parameters which are related to the above usages were also investigated: floating trash and bagasse, turbidity, bacteriological densities, nutrients, dissolved oxygen, temperature, salinity, bottom conditions, fish population, and toxicity (bioassay).

Conditions found in the outfall areas where the mills discharge wastes were compared with those found in nearby relatively unaffected control areas. This procedure allowed evaluation of the effects of mill operations on the quality and bottom characteristics of coastal waters adjacent to the mills. Data gathered during the offshore surveys are presented in Figures 14 through 31.

Figures 14 through 16 present observations of surface turbidity in the waters offshore from the three mills. Readings were obtained by towing behind the survey vessel a transmissometer which records turbidity as a percent transmittance of light. These readings were converted to Secchi disc equivalent (clarities) with tables furnished by the manufacturer which was followed by verification by field measurements. It was apparent from the outset of the study that turbidity patterns would not be consistent from day to day. Any attempt to average the daily values resulted in a star-like pattern radiating from the outfall and consequently the data are presented for single days only.

---

[6] Olokele Mill was selected for an offshore survey instead of McBryde Mill because it had a control area available. During the last offshore survey, Olokele Mill was forced to close because of weather conditions and some studies were conducted at the McBryde Mill also.

Figures 17 and 18 present total coliform results obtained from surface samples taken at Honokaa and Pioneer Mills discharge areas during a series of bacteriological tests in June and July 1968. Geometric means were computed for both areas but only results from the Honokaa formed a meaningful pattern. These data were obtained during the July 10-12 sampling period, while the Pioneer Mill data result from one day's sampling and typify a northwesterly traveling plume.

Figures 19 and 20 show patterns that were apparent from the total phosphate results at the Honokaa and Pioneer Mill discharge areas.

Figures 21 through 28 portray bottom conditions at the three mill outfall locations and control areas. These figures include sketches of selected bottom conditions and depictions of the condition and density of coral growths at selected mill sites. The color plates No. 1-8 portray at closer range and with more detail the conditions illustrated in the sketches.

Some extrapolation of findings was necessary to prepare the sketches reproduced in Figures 21 through 28 since excessive turbidities and high swells at the sampling sites often made underwater observations hazardous.

Figures 29 through 31 show the results of fish censuses which were conducted at all mill sites and control areas.

FLOATING TRASH AND BAGASSE

With one exception, all mills in Hawaii which dump liquid wastes directly to the sea, simultaneously dump waste trash (foliage) and bagasse. The trash generally floats on the water surface and is ultimately formed into "windrows" or rows of trash by the wind and ocean currents. These windrows are usually located near the outer edge of the turbid water zones and extend for long distances along the coast (Cover photograph and Plate 10).

The preliminary survey of all 26 sugar mills indicate that at least eight mills on the island of Hawaii and at least two mills on the island of Kauai regularly discharge cane and/or bagasse into the ocean.

Precise measurements of floating materials are difficult to make. Project field notes taken off the coastline of Hawaii record: "numerous mats of trash observed --largest was 300X15 feet" and "trash streaks existing on border of blue to green water." In later unnoted sightings, windrows were observed to extend for lengths greater than 300 feet. Surveillance of the coastline revealed accumulations of the material in public access areas as well as in inaccessible locations.

In addition to aesthetic considerations, floating trash is a source of complaint from local commercial fishermen because it fouls vessels and gear. The survey vessel used in this study also experienced the same problems.

TURBIDITY

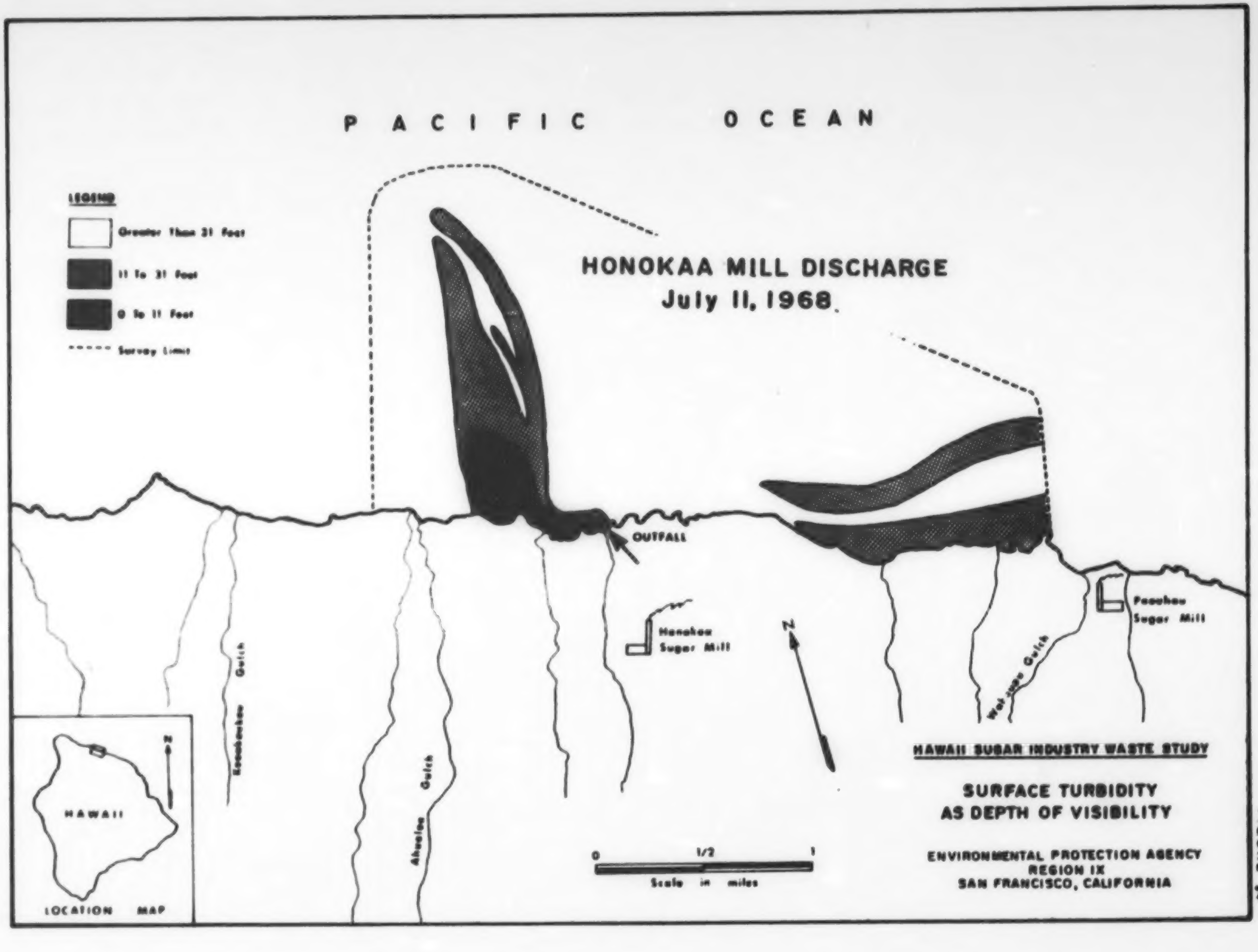
Turbid water around the three sample mills was characterized by a vertical stratification of silt which varied from less than a foot to several feet as the distance from the outfall increased. As diffusion continued, it eventually became impossible to record a definite interface between silt-laden water and sea water at any depth, and the water would ultimately show uniform turbidities to the bottom of the ocean or to the maximum length of the instrument cables.

Another characteristic of the turbid waters was its shape as a relatively narrow plume or streak. (See Cover photograph and Plate 10.) Shifting of the streaks was unpredictable and did not indicate an immediately apparent relationship with the tide cycles.

Actual measurements of turbidity were carried out by one or more of the following procedures: (1) use of a transmissometer to record transmittance of light at varying depths of water, (2) use of the Secchi disc to note the depth of visibility, and (3) use of water samples in the laboratory to test turbidity. Good correlations were obtained among all three types of measurements. The greatest amount of information was obtained by towing the transmissometer behind the boat which followed courses laid out perpendicular to the coastline above and below the outfalls. The results from three such "tows" are presented in Figures 14 and 15.

Honokaa Mill: Figure 14 illustrates the Honokaa plume on July 11, 1968. On this day, the plume was headed out to sea. The turbidity was swept westward for about a quarter mile along the small inlet, possibly because of local circulation in the bay. From there it was swept out to sea; inroads of clearer water entered the plume as its distance from shore increased. A rising tide was in progress throughout the measurements and tended to push the plume

FIGURE 14


PACIFIC OCEAN
LEGEND
Greater Than 21 Feet
11 To 21 Feet
0 To 11 Feet
Survey Limit
OUTFALL
Honokaa Sugar Mill
Paauhau Sugar Mill
N
Gulch
Ahualoa Gulch
Gulch
0
1/2
1
Scale in miles
HAWAII
N
LOCATION MAP

HONOKAA MILL DISCHARGE
July 11, 1968.

HAWAII SUGAR INDUSTRY WASTE STUDY

SURFACE TURBIDITY
AS DEPTH OF VISIBILITY

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

streaks in or along the coastline rather than outward toward the open sea. Light winds appeared from the east in the early morning and later on shifted to eleven knots from the northeast.

Two tongues of turbidity are shown on the eastern portion of the survey area (Figure 14). These streaks were apparently from the Paauhou Mill discharge. This indicates the variable current pattern along the Honokaa coast. During these measurements, surface currents were actually traveling in two different directions at close locations. Approximately 225 acres of surface water had clarities of less than 31 feet off the Honokaa outfall, with the outer edge reaching a distance of over a mile and a half from the discharge point.

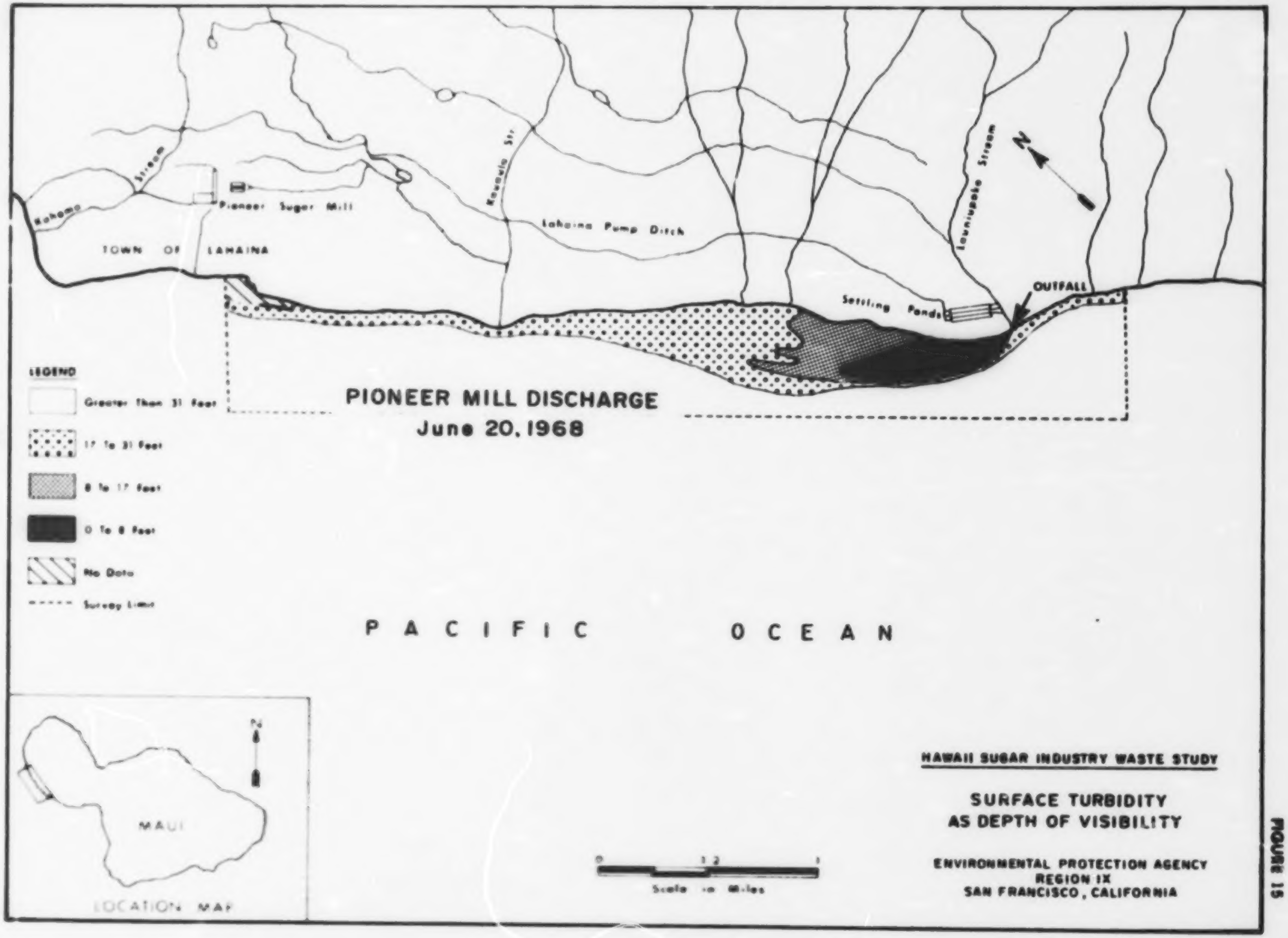
Pioneer Mill: Figure 15 illustrates the Pioneer Mill plume as it travels in its most common direction northwest along the coast. In general, the mill ceases to discharge its wastes at about 6:00 a.m. The pattern of discharge was determined by gathering data in the vicinity of the outfall while the discharge was continuing, and then by traveling along the coast into the plume after discharge from the outfall had ceased. All observations on this survey were taken at locations and at times such as to be uninfluenced by the terminated discharge.

In contrast to the rocky coastline at the Honokaa Mill, considerable amounts of sand were found along the shore near Pioneer Mill. As a result, the surf itself produced significant turbidities near the shore even though it was free from the influence of the discharge.

Figure 15 shows that abnormal turbidities were observed from the area of the outfall site to the approximate location of Kauaula Stream, a point about 2 1/2 miles along the coast from the discharge site. The 31-foot clarity line was extended from its location at the outer edge of the surf zone to an area approximately one-half mile from shore. More than 250 acres were affected by mill discharge. The depth of the turbidity was shallow near the outfall and was thin enough to be parted easily by the boat's wake, but the stratification diminished with distance and ultimately became indistinguishable.

McBryde Mill: Most of the offshore surveys on the island of Kauai were conducted in the vicinity of the Olokele Mill, however, adverse weather conditions during the spring survey forced this mill to close. Since McBryde Mill continued to operate during this period, it was studied in lieu of the Olokele Mill for the last survey.

FIGURE 15


PIONEER MILL DISCHARGE
June 20, 1968
LEGEND
Greater Than 31 Feet
17 To 31 Feet
8 To 17 Feet
0 To 8 Feet
No Data
Survey Limit
PACIFIC OCEAN
Kahoma Stream
Pioneer Sugar Mill
TOWN OF LAHAINA
Kauaula Str.
Lahaina Pump Ditch
Launiupoko Stream
Settling Ponds
OUTFALL
N
0
1/2
1
Scale in Miles
N
MAUI
LOCATION MAP

HAWAII SUGAR INDUSTRY WASTE STUDY

SURFACE TURBIDITY
AS DEPTH OF VISIBILITY

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

Also, in addition to the discharges from the Olokele Mill, one discharge from the McBryde Mill was also studied. The latter discharge was observed entering the sea on April 27; so transmissometer measurements were made on that plume as an additional observation (Figure 16). Investigation revealed that the mill had ceased operation during the previous night even though cooling water was being passed through the bottom of the final detention pond. This discharge was not true washwater, but cooling water which contained significant amounts of material that had been scoured from the reservoir. Although the discharge did not typify everyday wash-water effluents, such discharges obviously occur and subsequently affect the receiving waters in the manner indicated.

Rainfall and ensuing runoff were responsible for the band of water shown with clarities of 17 to 31 feet. The band flowed along the coastline for about one half mile offshore and was visible to the east of the mill discharge.

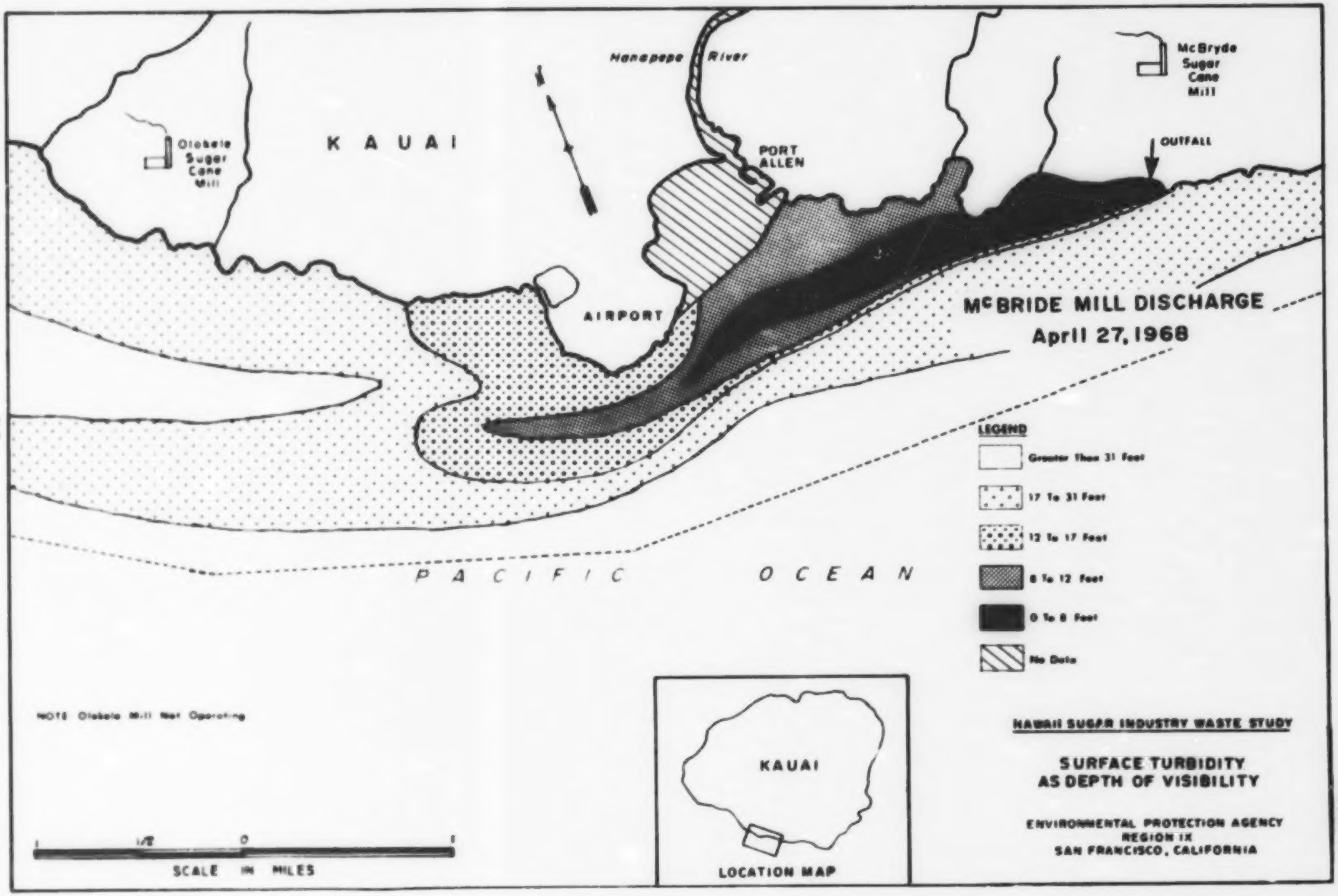
The mill discharge formed a bright reddish-brown streak, closely approximated on Figure 16 by the darkest zoning. This streak continued to flow for about two and a half miles from the actual discharge point before diffusion sufficiently dispersed it. Turbidity attributable to the outfall continued for at least another mile along the coastline.

Large discharges from the Hanapepe River were observed on the previous day, April 26, but on the survey date of April 27 these discharges were considerably diminished. The turbid water off the Olokele Mill was observed to be split by a tongue of clearer water probably resulting from a counter ocean current. Runoff from the Hanapepe River and other sources in the area tend to mask the mill's effects. At least 1,000 acres of the ocean's surface turbidity, however, were increased by the mill discharge.

Discussion of Turbidity: Efforts were made to test turbidity under "natural" conditions; i.e., conditions observed at locations near a discharge point but obviously not under the influence of the discharge. To do this, one survey was scheduled in the winter season when the mills were shut down and the three selected control areas on each island were also sampled at the same time.

In summary, the results indicated that when significant swells existed, clarity near the shoreline was as low as two feet if sand or other fine material was in the vicinity. The Secchi disc measurement equivalents in the water beyond the influence of the swells always exceeded 30 feet, and on

FIGURE 16


Hanapepe River
McBryde Sugar Cane Mill
Olokele Sugar Cane Mill
KAUAI
PORT ALLEN
OUTFALL
AIRPORT
McBRIDE MILL DISCHARGE
April 27, 1968
PACIFIC OCEAN
LEGEND
Greater Than 31 Feet
17 To 31 Feet
12 To 17 Feet
8 To 12 Feet
0 To 8 Feet
No Data
NOTE Olokele Mill Not Operating
1 1/2 0 1
SCALE IN MILES
KAUAI
LOCATION MAP
HAWAII SUGAR INDUSTRY WASTE STUDY
SURFACE TURBIDITY AS DEPTH OF VISIBILITY
ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

many occasions a Secchi disc or other piece of equipment could be visible at depths of 100 feet.

Measurements were taken on two occasions when the waters were effected by the storm runoff. The clarity of the ocean at the shoreward Maui control station in January was observed to be 38 feet, whereas the value normally would be twice this amount.

Of the 26 sugar mills in the State of Hawaii, three mills present no turbidity problems one is scheduled to close in 1971, five have only minimal discharges, and 17 have significant discharges of which ten can be labeled as overtly offensive from the standpoint of turbidity. The study found that discharge plumes are capable of discoloring the ocean surface for miles. Observations made of irrigation tailwater discharges during the various surveys revealed that these waters also discolor large areas of the ocean.

Discoloration of the waters of Hawaii is diametrically opposed to the goals of the visitor industry which is second only the Federal-military establishment in total contribution to the State's economy. The visitor industry which describes the "continuous clear blue sparkling waters" of the State to potential tourists housed more than one million tourists in 1967, a 25.4 percent increase over the previous years. When the tourist industry was smaller, there was little conflict between the two. Predictions have been made that tourism will become increasingly more significant to the future of the Islands. Today, resort complexes stand where previously only agricultural or grazing land existed, and more such developments are proposed.

BACTERIOLOGICAL DENSITIES

Bacteriological results from the ocean sampling program are limited to total coliforms. No fecal coliform determinations were conducted on receiving waters because they could not be run in a technically acceptable manner aboard the survey vessel, nor could ocean samples be processed on shore because the time interval between taking the samples, and docking the vessel, was too excessive to meet acceptable standards for validity. It was possible, on the other hand, to obtain reliable results for fecal coliform levels in the mill wastes themselves; therefore, the latter were used to evaluate the effects of this parameter.

In general the bacteriological densities were directly related to the proximity of the mill outfalls and location within the plume. For example, if the plume had a distinct edge, the densities would be relatively high in the plume and low a few feet outside of it. Like turbidity, coliform densities diffused with depth and distance.

Honokaa Mill: Figure 17 shows the geometric mean values for total coliform concentrations during four sampling periods conducted on July 10-12. Field notes during the period indicated also that the area of discoloration followed patterns similar to those shown in Figure 17. The average densities exceeded 10,000/100 ml, for a surface area of about 90 acres surrounding the mill outfall. The numbers then diminished in a northeasterly direction to 200/100 ml (Figure 12) and reached a maximum distance of about one mile from the outfall.

No observations were made near the Paauhau Mill or for more than two miles west of the Honokaa outfall.

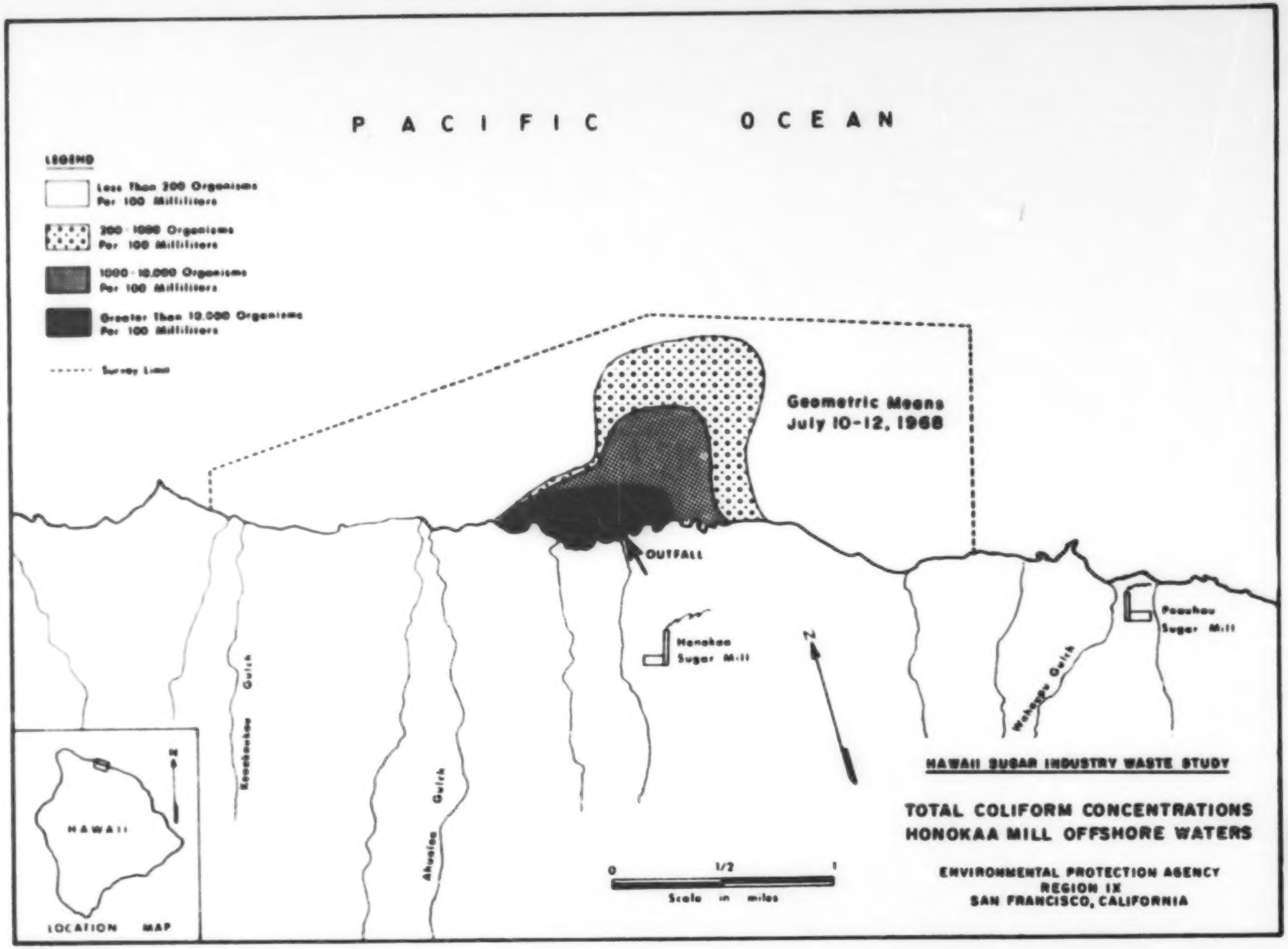
Pioneer Mill: Figure 18 indicates the total coliform values observed in the offshore waters of Pioneer Mill on June 21. As previously noted, sampling was done on other days but meaningful patterns could not be obtained from the averages because of the varying directions of the plume. In this case, the plume was observed to be heading northwest along the coast in a pattern similar to that appearing in Figure 18. Densities as high as 5000/100 ml, were observed at a distance of approximately 2 miles from the outfall.

Discussion: Total coliform values in control area waters at Maui and Hawaii consistently gave values of less than 100/100 ml, with one exception. Values were less than 10/100 ml in over 50 percent of the samples. Similar results were obtained from samples taken near the outfalls when there was no visible turbidity.

The mill surveys showed that the discharges, before release to the coastal waters were high in both total and fecal coliforms, representing a potential hazard to health.

After release of the mill discharge to the ocean, the Pioneer Mill plume (Figure 18), indicating the result of one day's sampling, shows a surface area of more than 250 acres in which total coliform densities exceed 1000/100 ml, a generally accepted limit for water classified as "safe" for water contact sports. The distance that the elevated densities continued is a matter of speculation; however, based on a count of 3400/100 ml at the westernmost sampling point, densities greater than 1000/100 ml may have existed at a distance offshore from Lahaina, a town located three miles west of the discharge point.

FIGURE 17

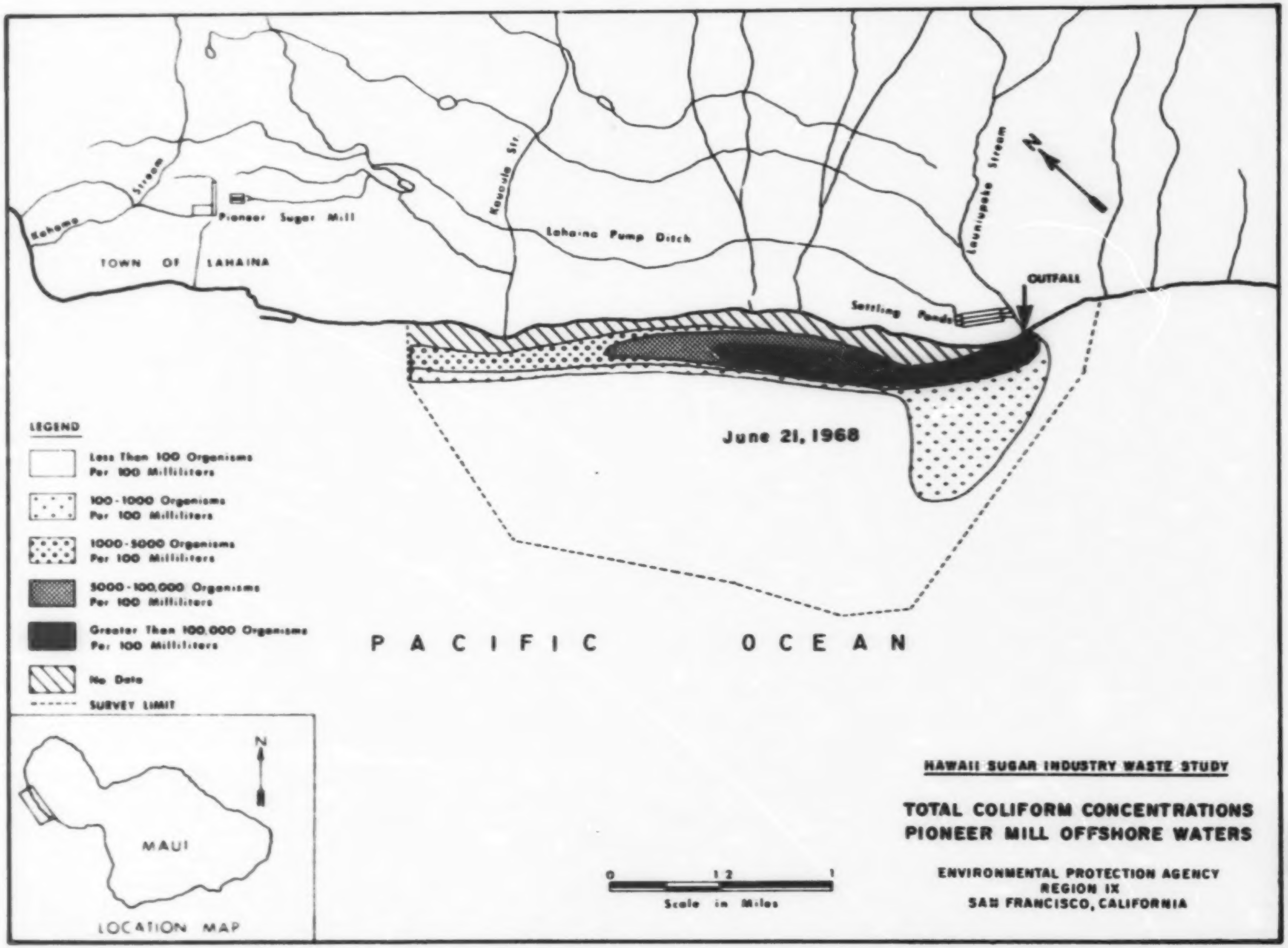

PACIFIC OCEAN
LEGEND
Less Than 200 Organisms Per 100 Milliliters
200 - 1000 Organisms Per 100 Milliliters
1000 - 10,000 Organisms Per 100 Milliliters
Greater Than 10,000 Organisms Per 100 Milliliters
Survey Limit
Geometric Means July 10-12, 1968
OUTFALL
Honokaa Sugar Mill
Paauhau Sugar Mill
Waikoekoe Gulch
Ahualoa Gulch
Kaaahaukau Gulch
N
0
1/2
1
Scale in miles
HAWAII
N
LOCATION MAP

HAWAII SUGAR INDUSTRY WASTE STUDY

TOTAL COLIFORM CONCENTRATIONS
HONOKAA MILL OFFSHORE WATERS

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

FIGURE 18


Kahoma Stream
Pioneer Sugar Mill
TOWN OF LAHAINA
Kauaula Str.
Lahaina Pump Ditch
Launiupoko Stream
N
OUTFALL
Settling Ponds
June 21, 1968
PACIFIC OCEAN
LEGEND
Less Than 100 Organisms Per 100 Milliliters
100-1000 Organisms Per 100 Milliliters
1000-5000 Organisms Per 100 Milliliters
5000-100,000 Organisms Per 100 Milliliters
Greater Than 100,000 Organisms Per 100 Milliliters
No Data
SURVEY LIMIT
MAUI
LOCATION MAP
0
1 2
1
Scale in Miles

HAWAII SUGAR INDUSTRY WASTE STUDY

TOTAL COLIFORM CONCENTRATIONS
PIONEER MILL OFFSHORE WATERS

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

After entering the sea, bacterial densities diminish at a significant rate with increasing distance from the point of discharge. Although the toxicity of sea water to bacteria is not acknowledged by all authorities, a decrease in density did exist and it appears that the decrease is due both to dilution as well as the natural toxicity of sea water to the organisms. If a shoreline is rugged, remote, and generally inaccessible for water contact sports, the actual health hazard of these discharges may be minimal. If, however, the shoreline is accessible, is composed of sandy beaches, and has breaking swells that appeal to surfers and swimmers, a health hazard does exist. This statement is based not only on the total coliform densities actually observed in the sea, but also on the large amounts of fecal coliforms (up to 1,000,000/100 ml) which are known to exist in the mill wastes. It has been suggested that mill discharge areas be zoned to prohibit people from using these discolored waters for body contact sports, but during the surveys it was observed that these waters were used by numerous surfers.

It is obvious that a hazard to health exists in waters throughout the State which are under the influence of these mill discharges and are accessible for recreation. Under average conditions of velocity and direction of both wind and ocean currents, water over two miles away from an outfall may have a significant density of bacteria to raise doubt as to its safety. The discharge from Pioneer Mill is a prime example of effluent drifting into water recreation areas, and there are similar situations on all four sugar-producing islands where surfing, shoreline fishing, sport fishing from boats, and swimming are practiced in areas that can be affected by mill wastes.

NUTRIENTS

The results obtained for the values of phosphate are considered fairly precise, (± 0.004 mg/l-50 ml sample), however, the nitrogen values are only precise to ± 0.1 mg/l. This level of accuracy is due to the precision of the laboratory procedure for Kjeldahl nitrogen which forms the largest portion of the total nitrogen value.

Total Phosphorus: The total phosphorus values at the near shore stations off Honokaa Mill generally showed either uniform distribution from top to bottom, or higher values at the surface in the plumes. The depth of water increases rapidly offshore of the mill, and during the spring survey higher values were noted near the bottom at the deep water stations. These figures formed a semi-circular pattern and are presented in Figure 19. The plume was also observed to be traveling in the same pattern during the sampling period.

Total phosphorus values offshore of Pioneer Mill showed fairly uniform distribution from top to bottom except near the outfall where the effect of the plume stratification was noted. Results from samples taken at the deeper water locations showed less evidence of higher values at the bottom. An elliptical pattern was noted in the values during the June survey and is shown in Figure 20. The observed turbidities also formed a similar pattern.

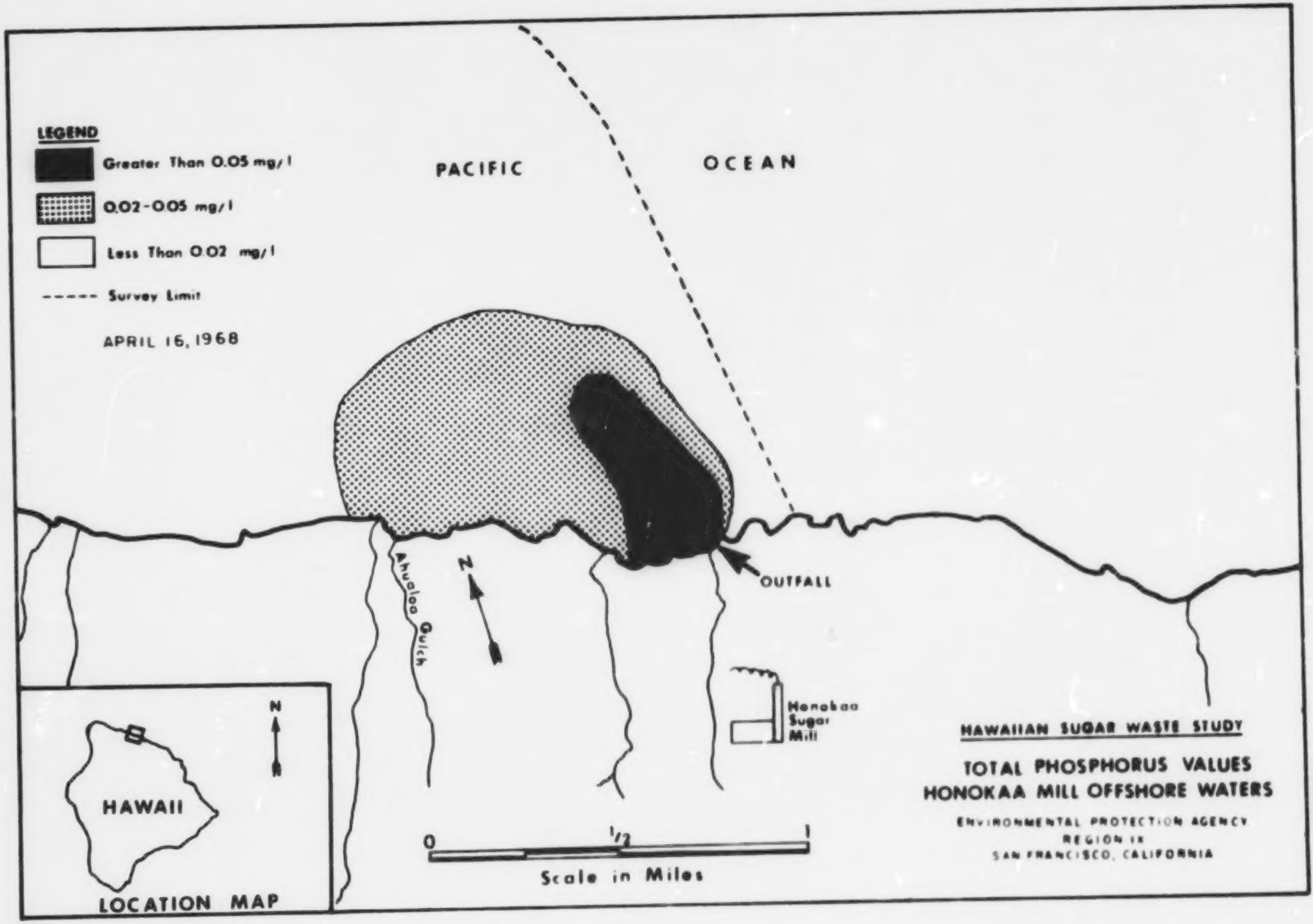
Total phosphorus values off Olokele Mill were generally lower than values obtained from the waters near the Pioneer Mill discharges, and deeper water samples showed little variation from top to bottom.

Total phosphorus results from all three control areas ranged from a high of 0.023 mg/l to a low of 0.009 mg/l, with an arithmetic mean of 0.015 mg/l. Values of phosphorus obtained at distances beyond the visible influence of mill discharges were comparable to those values obtained at the control sites.

The in-plant surveys revealed that the mill wastes contained significant concentrations of total phosphorus, and Figures 19 and 20 show that the discharges can be detected for some distance from the outfall locations at Honokaa and Pioneer Mills. No similar pattern could be recognized in the Olokele discharge because of a smaller volume of effluent. The figures indicate that the numerical values for normal sea water were exceeded for a distance of approximately one mile in the direction of the travel of the plume at both Honokaa and Pioneer Mills on April 16 and June 19, respectively. Approximately 375 acres of surface waters showed phosphorus values over 0.02 mg/l at both mills on those days.

Despite the relatively large amounts of phosphate contained in the discharge of the mills, the effect of dilution in the sea reduces the surface area of abnormal phosphate values to less than 400 acres. Because of the small volumes, the effluents from Olokele Mill affected the receiving waters only in the very near vicinity of the outfall. Since all three mill discharges are exposed to ocean currents, the water is constantly moving past, and thus minimizing the formation of any standing crop of phytoplankton in the vicinity. Benthic algae were present off the Olokele Mill, indicating enrichment may be occuring in the vicinity of this outfall. Crops of the algae were not as

FIGURE 19

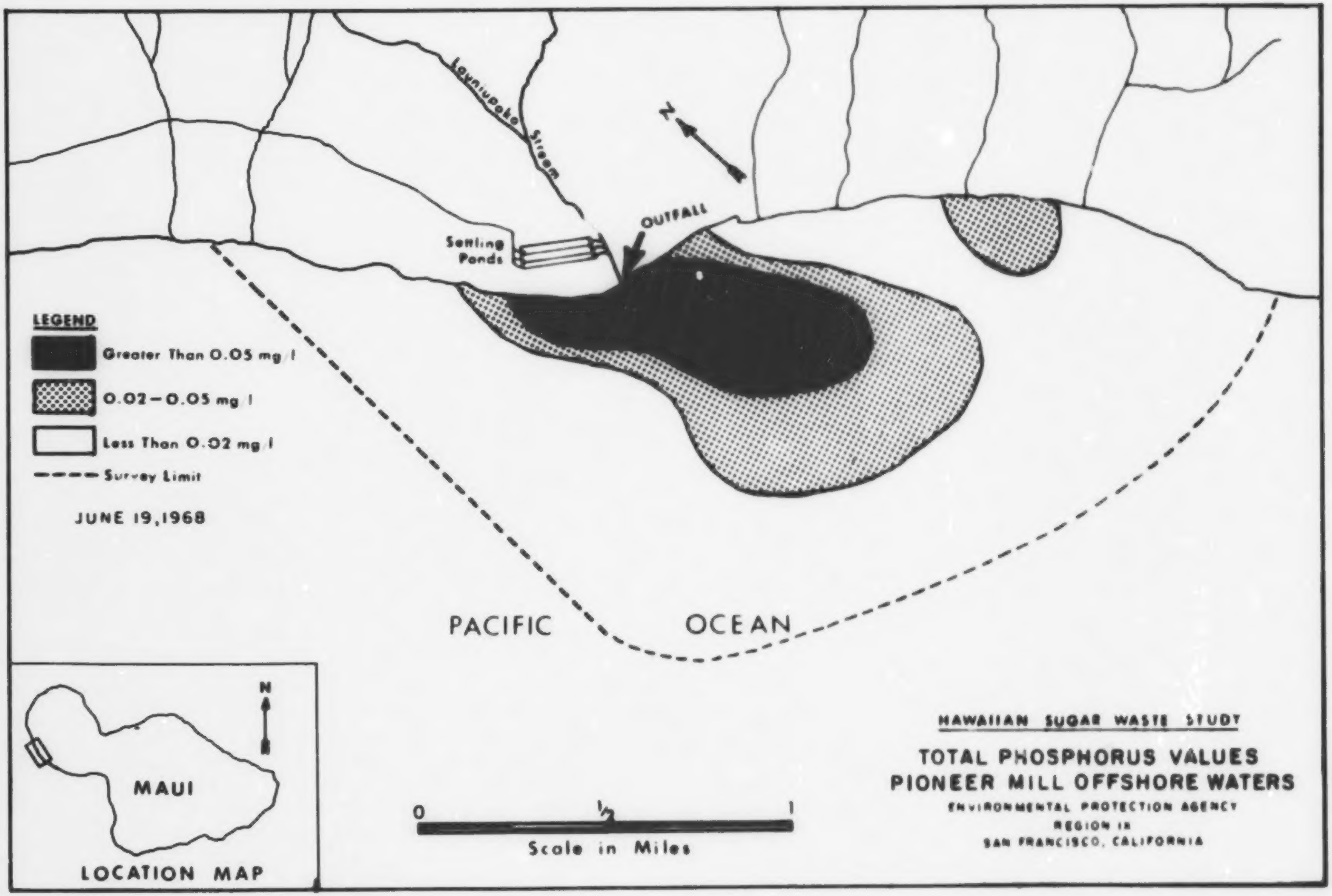

LEGEND
■ Greater Than 0.05 mg/l
▨ 0.02-0.05 mg/l
☐ Less Than 0.02 mg/l
----- Survey Limit
APRIL 16, 1968
PACIFIC
OCEAN
OUTFALL
Ahualoa Gulch
N
Honokaa Sugar Mill
0
1/2
1
Scale in Miles
HAWAII
N
LOCATION MAP

HAWAIIAN SUGAR WASTE STUDY

TOTAL PHOSPHORUS VALUES
HONOKAA MILL OFFSHORE WATERS

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

FIGURE 20


Launiupoko Stream
Settling Ponds
OUTFALL
N
PACIFIC OCEAN
LEGEND
Greater Than 0.05 mg/l
0.02—0.05 mg/l
Less Than 0.02 mg/l
Survey Limit
JUNE 19, 1968
0
1/2
1
Scale in Miles
MAUI
N
LOCATION MAP

HAWAIIAN SUGAR WASTE STUDY

TOTAL PHOSPHORUS VALUES
PIONEER MILL OFFSHORE WATERS
ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

pronounced at the Honokaa and Pioneer Mill outfalls and their presence at those sights may be a function of bottom topography, current patterns, and seasonal variation.

Total Nitrogen: Values of total nitrogen at the Honokaa control area at Waimanu Valley varied from less than 0.1 mg/l to 0.4 mg/l, with an overall mean of 0.2 mg/l. Values at Pioneer control area ranged from less than 0.1 to 0.8 mg/l, with an overall mean of 0.3 mg/l. The Poipu control area on Kauai showed values ranging from 0.1 mg/l to 0.8 mg/l, with an overall mean of 0.35 mg/l.

Higher nitrogen values were observed in the immediate vicinity of all three mill outfalls, and maximum values of 2.8, 0.9, and 0.5 mg/l were observed in the surface waters at the Honokaa, Pioneer, and McBryde Mills, respectively. Offshore waters located beyond the visible influence of the mills showed values ranging from less than 0.1 mg/l to 0.3 mg/l.

The data indicate that ammonia and the inorganic forms of nitrogen form only a small fraction of the total nitrogen value. Laboratory determination of the organic fraction is difficult at concentrations less than 0.1 mg/l. Mean values of nitrogen off the control areas, which were considered to be free from any proximate pollutants, were all in excess of 0.15 mg/l. This value is not uncommon in near shore waters not receiving artificial stimulation because of influence of inflow from land and biological activity in shallow waters. Some of the values near the mills, free of the visible influence of the discharges, also had values in excess of 0.15 mg/l.

DISSOLVED OXYGEN

The control waters for all three mills showed oxygen saturations in excess of 90 percent (5.8 mg/l at 28°C), with the exception of the bottom samples taken at the stations located one mile off the island of Kauai and Hawaii. The depth at these stations reached about 600 feet, and on occasion oxygen saturation ranged between 80 and 90 percent. This condition can be attributed to settled and decomposing plankton and other organic matter on the ocean floor.

All sampling in the Honokaa offshore waters gave saturation values in excess of 95 percent, with the exception of the deep water bottom stations which exhibited results in the 80 to 90 percentage range and were similar to the results for the water control station.

A saturation value of 77 percent was observed on one occasion near the surface of the water in the vicinity of the Pioneer Mill outfall. All other samples in the area showed saturation in excess of 90 percent.

The lowest values in the waters around the Olokele Mill for dissolved oxygen were obtained during the winter survey when the mill was inoperative. Several samples were noted in the 80 percent range, with one value as low as 71 percent. Values in the autumn and spring during actual mill operation ranged from a low of 90 percent to greater than 100 percent, excluding the deep water stations.

The effect of the mill discharges on dissolved oxygen levels is therefore considered to be minimal.

TEMPERATURE

Seasonal variations in temperature were observed to range between two and four degrees centigrade, however, no significant rises above ambient conditions were observed near the discharge points. In the discharge areas, surface temperatures varied from a low of 23.6°C in January to a high of 28.8°C in September. The lowest bottom temperature was 16.5°C and that was recorded at a depth of [illegible]00 feet off of the Honokaa Mill outfall.

The effect of the mill discharges on ocean water temperature is considered to be minimal.

SALINITY

Only minor depressions in salinity were noted in the surface samples taken near the Honokaa and Pioneer Mill outfalls. No significant changes were observed in samples from the Olokele discharge area. The stratification of the effluent from Honokaa and Pioneer Mills was indicated by slightly higher salinity values found in samples taken near the ocean bottom in the vicinity of the discharge.

The degree of diffusion of the mill discharges is indicated by the absolute values of salinity near the outfalls. Analyses showed that even with the relatively low salinity content of actual discharges, the receiving waters had values only slightly less than natural salinity of sea water near the discharge points, with no noticeable difference found only a few hundred feet away. Salinity measurements indicated that the actual discharges were subjected to an immediate and extensive diffusion upon entering the sea, although turbidity measurements indicated

Plate 1.--Honokaa Mill Outfall. Bottom formations of dead coral eroded by wave and current action at 18 foot depth.

Plate 2.--Honokaa Mill Outfall. Barren substrate at 25 foot depth once covered with coral, now contains algae and sponges.

Plate 3.--Honokaa Control Area. Boulder zone at 40 foot depth with healthy coral growth of *Pocillopera meandrina* heads (center and right) and *Porites lobata* mounds (left).

Plate 4.--Pioneer Mill Outfall. Sea urchin with cane trash on dorsal surface grazes on silt-laden algae which cover dead coral at 10 foot depth.

Plate 5.--Pioneer Mill Outfall. Approximately 250 yards from outfall, coral becomes denser, corallums larger, and algae (Turbinaria) cover bottom between corals.

Plate 6.--Pioneer Control area. A dense coral reef supporting abundant marine life extends approximately 300 yards offshore.

Plate 7.--Olokele Mill Outfall. Soil particles entrapped in thalli of Turbinaria color the bottom red at Kaumukani Point. Black sponges (Demospongia) are common in area.

Plate 8.--Olokele Control Area. Luxuriant growth of several coral species covers over half of bottom topography.

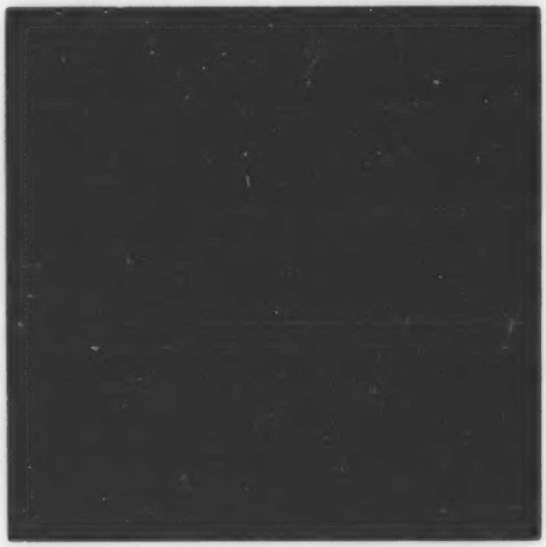


Plate 9.--Aerial view of Olokele Sugar Mill and ocean outfall on Kauai.

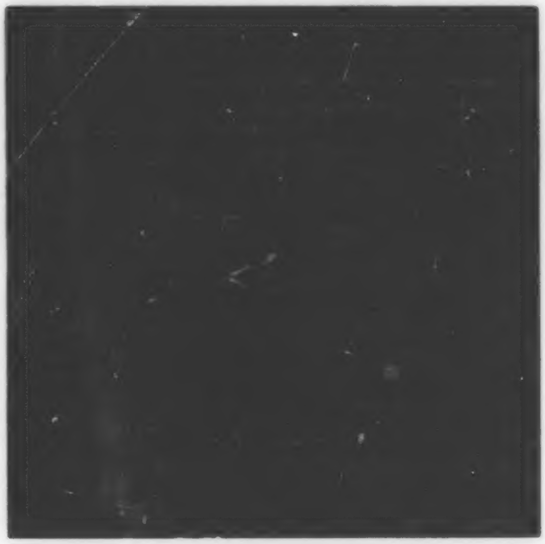


Plate 10.--Site of Honokaa Mill outfall discharge off Hamakua Coast of Hawaii.

Plate 11.--McBryde Sugar Mill on Kauai Coast showing clarifier and settling pond (center, right).

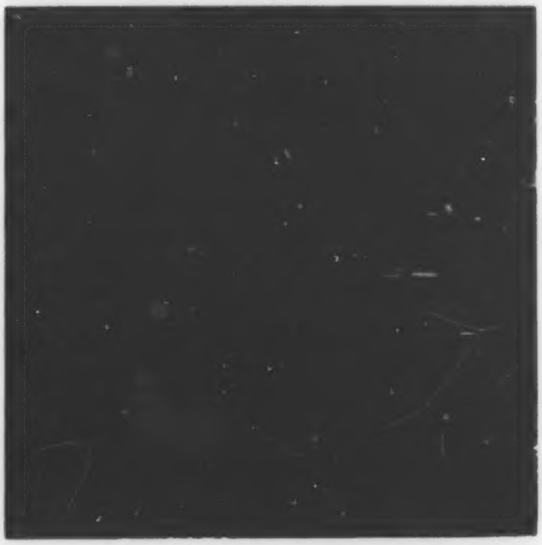


Plate 12.--Pioneer Sugar Mill with adjacent canefields borders Lahaina on the island of Maui.

that vertical stratification did persist for several hundred feet from the discharge point. The effect of such vertical stratification was not evident in the salinity data.

BOTTOM CONDITIONS

Project divers secured data concerning bottom conditions by scuba-diving to obtain visual observations. Similar survey procedures were conducted at both the outfall areas and the control areas.

High ground swells and turbidity near the mills persistently limited conduct of the survey. Turbidity impaired observations and increased the hazard to the divers. Presentation of the bottom conditions are shown in Figures 21 through 28 and Plates 1 through 8. Bottom surveys at each mill will be discussed separately.

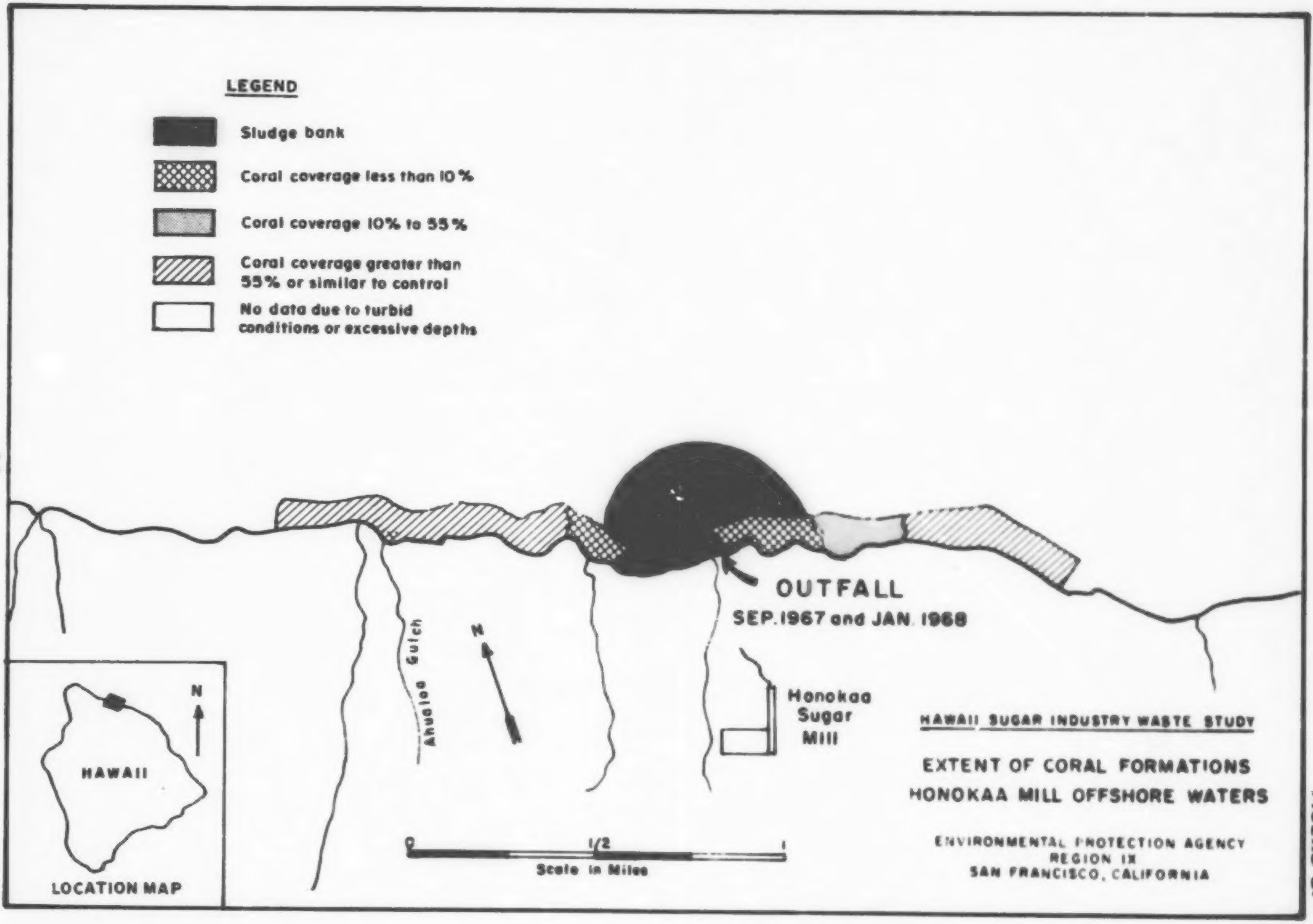
Honokaa Mill: An extensive sludge bank consisting of cane trash, bagasse, and silt was found in the outfall area of the Honokaa Mill (Figure 21). The figure also shows that coral growth was retarded along the coastline on both sides of the outfall for a distance of about 0.75 mile. Growths of sponge and benthic algae were evident in the areas of diminished coral concentrations. The coastline is characterized by excessive depths caused by a steep gradient a short distance from shore.

Figure 22 depicts inshore bottom conditions observed about 100 yards east of the actual mill outfall. The bottom in the area is characterized by the ledges shown in the upper portion of the illustration, together with the pockets of sludge and cane trash shown in the bottom portion of the figure. These ledges were covered with dead coral growth.

Plates 1 and 2 depict bottom formations in 18 and 25 feet off the mill outfall. The sludge deposits were approximately 10 feet deep, and thin layers of silt were observed along the rocky ledges. Dead coral eroded and rounded from wave and current action characterized this area (Plate 1). Sponges and benthic algae were also present along the barren rocky surfaces which were once covered with coral (Plate 2).

Figure 23 and Plate 3 illustrate the bottom conditions at the Honokaa control area which was located off Waimanu Valley. Although the bottom topography is similar to that area off the mill outfall, however, the figure shows

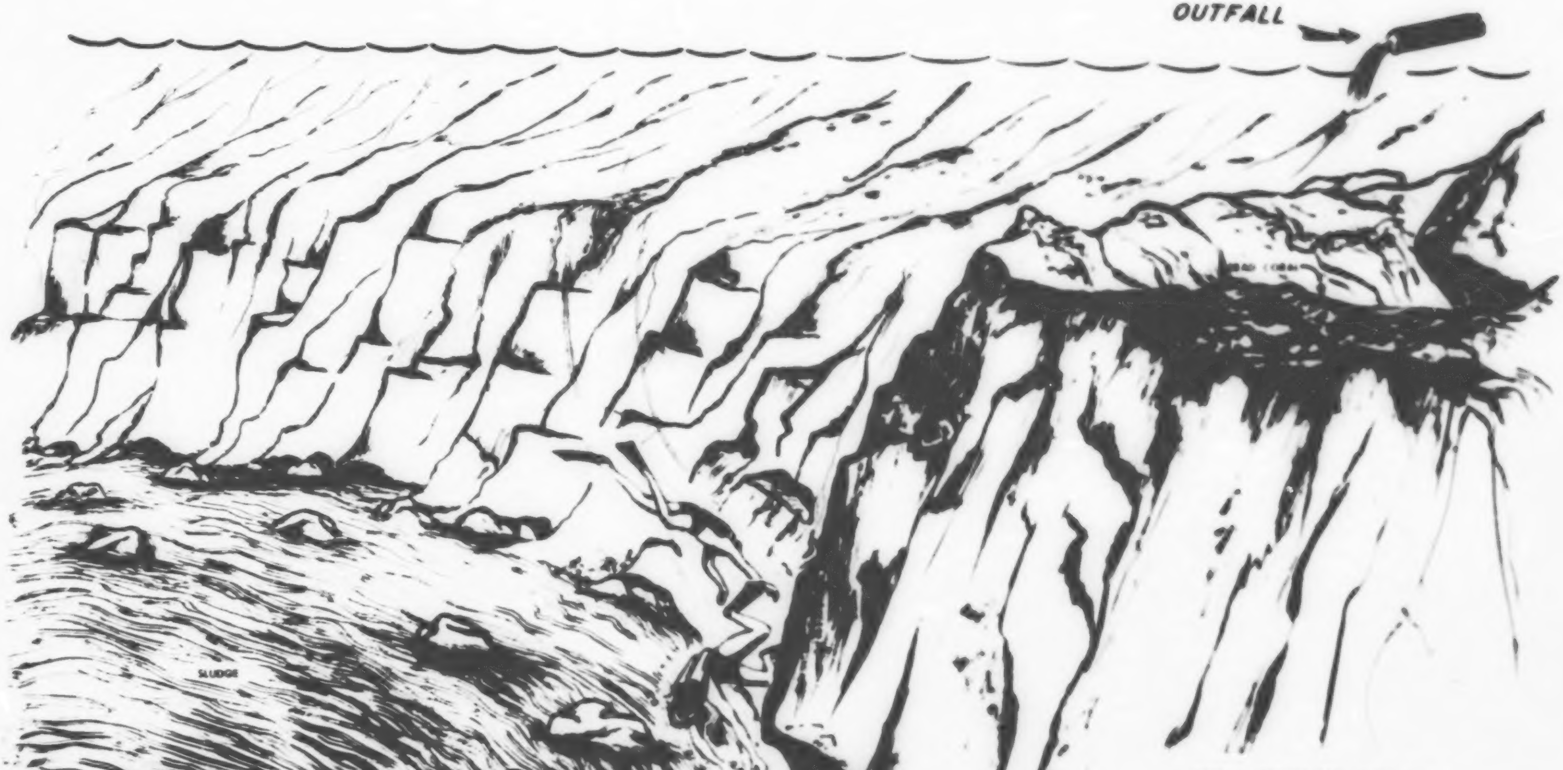
FIGURE 21


LEGEND
■ Sludge bank
▩ Coral coverage less than 10%
▒ Coral coverage 10% to 55%
▨ Coral coverage greater than 55% or similar to control
☐ No data due to turbid conditions or excessive depths
OUTFALL
SEP. 1967 and JAN. 1968
Honokaa Sugar Mill
Ahualoa Gulch
N
0
1/2
1
Scale in Miles
HAWAII
N
LOCATION MAP

HAWAII SUGAR INDUSTRY WASTE STUDY

EXTENT OF CORAL FORMATIONS
HONOKAA MILL OFFSHORE WATERS

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

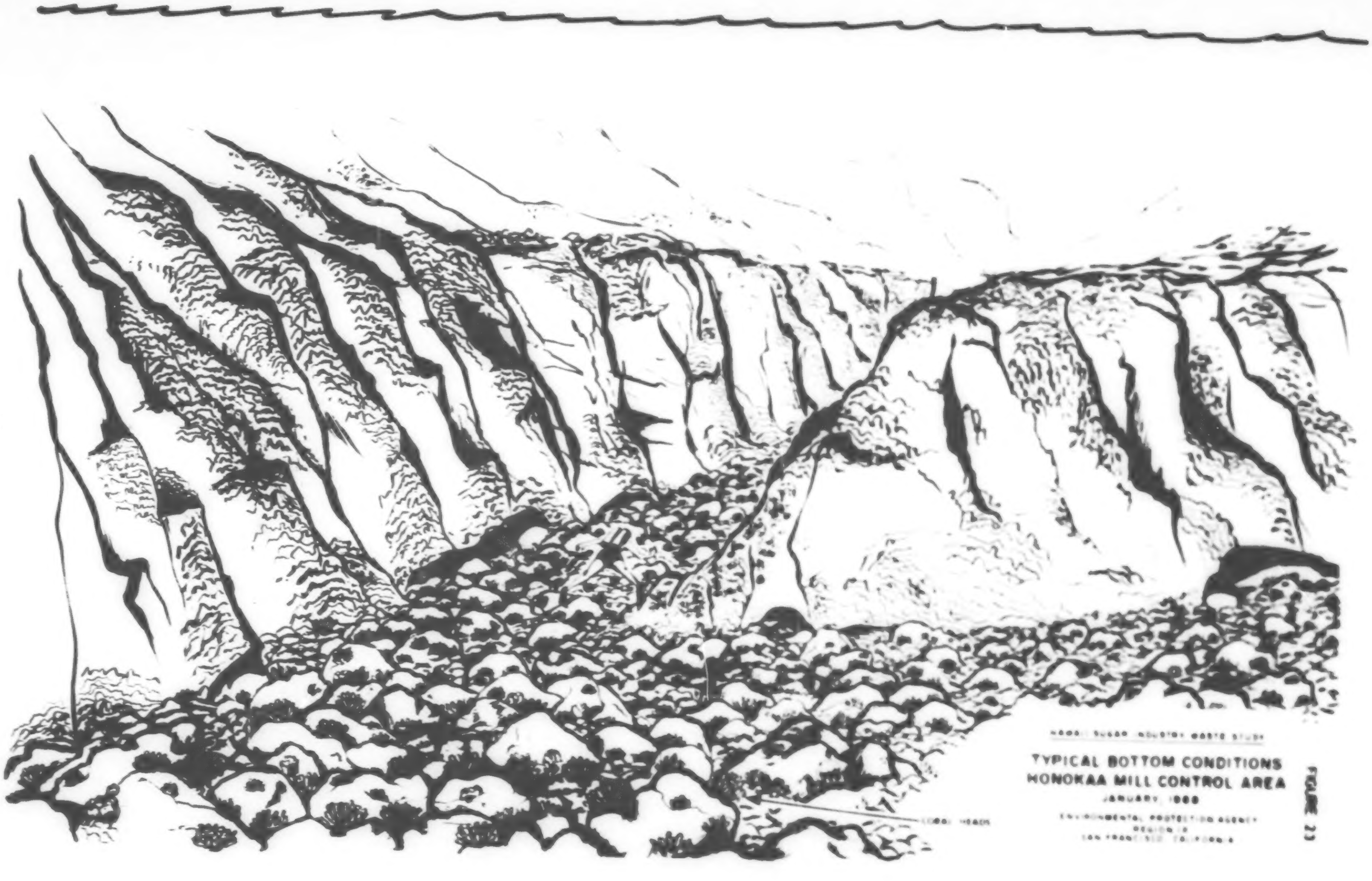


HAWAII SUGAR INDUSTRY WASTE STUDY

BOTTOM CONDITIONS
HONOKAA MILL OUTFALL AREA
JANUARY, [illegible]

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

FIGURE 22



HAWAII SUGAR INDUSTRY WASTE STUDY

TYPICAL BOTTOM CONDITIONS
HONOKAA MILL CONTROL AREA
JANUARY, 1969

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

FIGURE 23

extensive coral growth. Observations revealed that between 65 and 75 percent of the bottom of the control area was covered with healthy coral growths. Plate 3 depicts the Honokaa control area at a depth of 40 feet.

Pioneer Mill: Figure 24 and Plates 4 and 5 show the bottom conditions from a point about 300 yards off the mill outfall to a point about 50 yards from the outfall.

As seen from the figure, coral growth is negligible near the outfall but grows more densely as distance from the outfall increases. In a depth of 10 feet of water, silt covered algae and dead coral were found (Plate 4). Bottom conditions 50 yards from the outfall showed a consistency of 75 percent sand interspersed with rocks and dead coral. Thin layers of silt were present which diminished with distance from the outfall. Benthic algae and sponges were sighted in the areas of thin coral coverage and these were generally covered with a layer of silt. At approximately 250 yards off the outfall, coral densities increased and corallums became larger (Plate 5).

Figure 25 and Plate 6 show typical bottom conditions in the Pioneer Mill control area from about 150 to 300 yards off shore. An extensive coverage of coral heads and an abundance of sea life were found in the control area from the shore to the end of the reef.

Olokele Mill: Underwater surveys of the benthos were conducted at five locations off the island of Kauai. In addition to surveying the control area off Poipu Beach which was also used for chemical sampling, observations were made at a second control area located about 0.75 mile east of the Olokele discharge. Two control areas were selected because they depicted differences in the bottom topography which existed in the vicinity of the mill discharges.

Figures 26 and 27 show, respectively, bottom conditions near the Olokele Mill's main outfall and bottom conditions at the control area, located 0.75 mile east of the mill. The outfall area (Figure 26) contained few coral heads and the dominant life form was a benthic algae which covered much of the rock surface. Sponges were present and the sand deposits in the open depressions were relatively free of silt deposits (Plate 7).

In contrast, the overall topography of the control area consisted of a flat bottom with a minimum of outcroppings. The bottom life was considerably different with

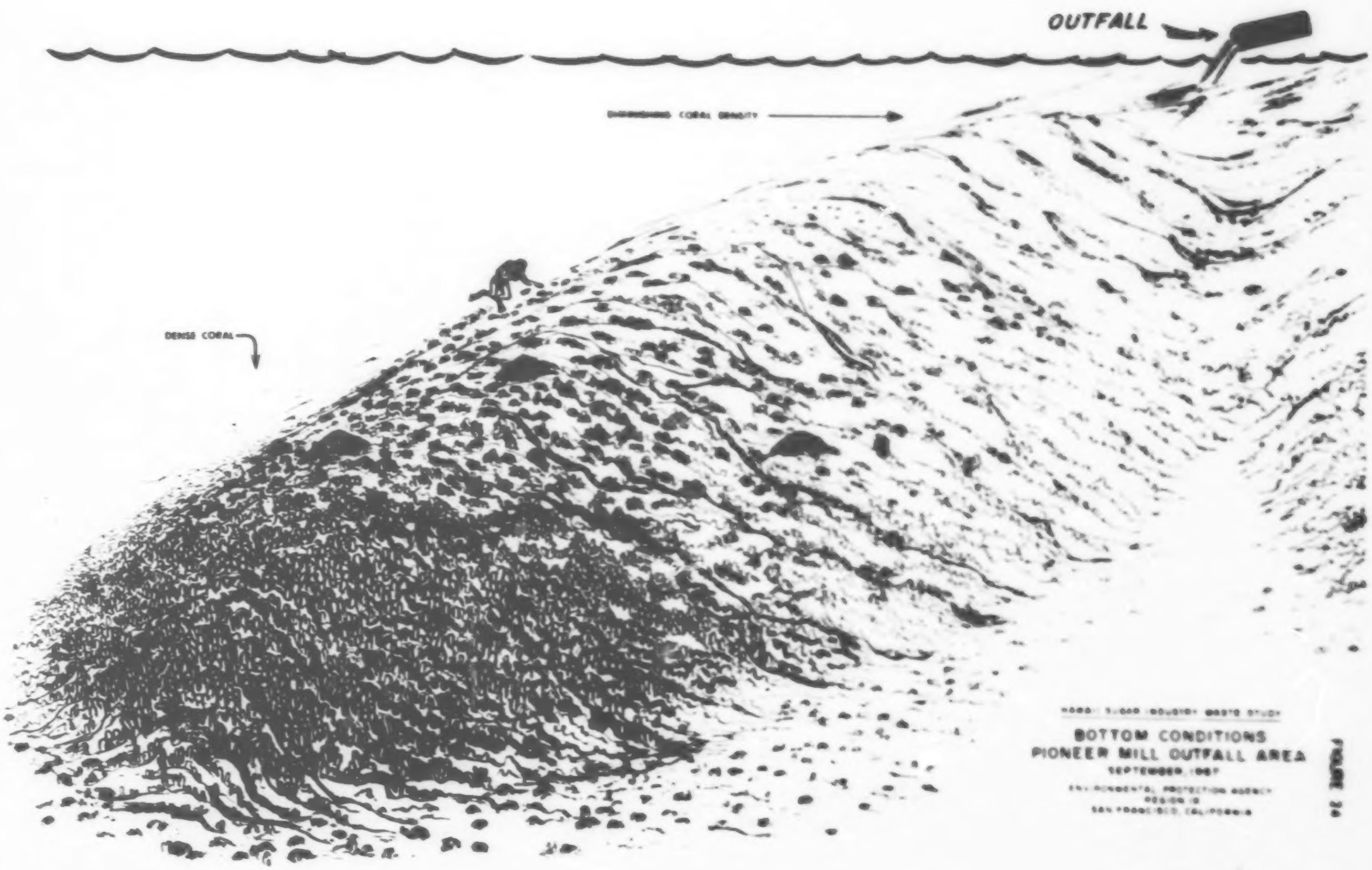
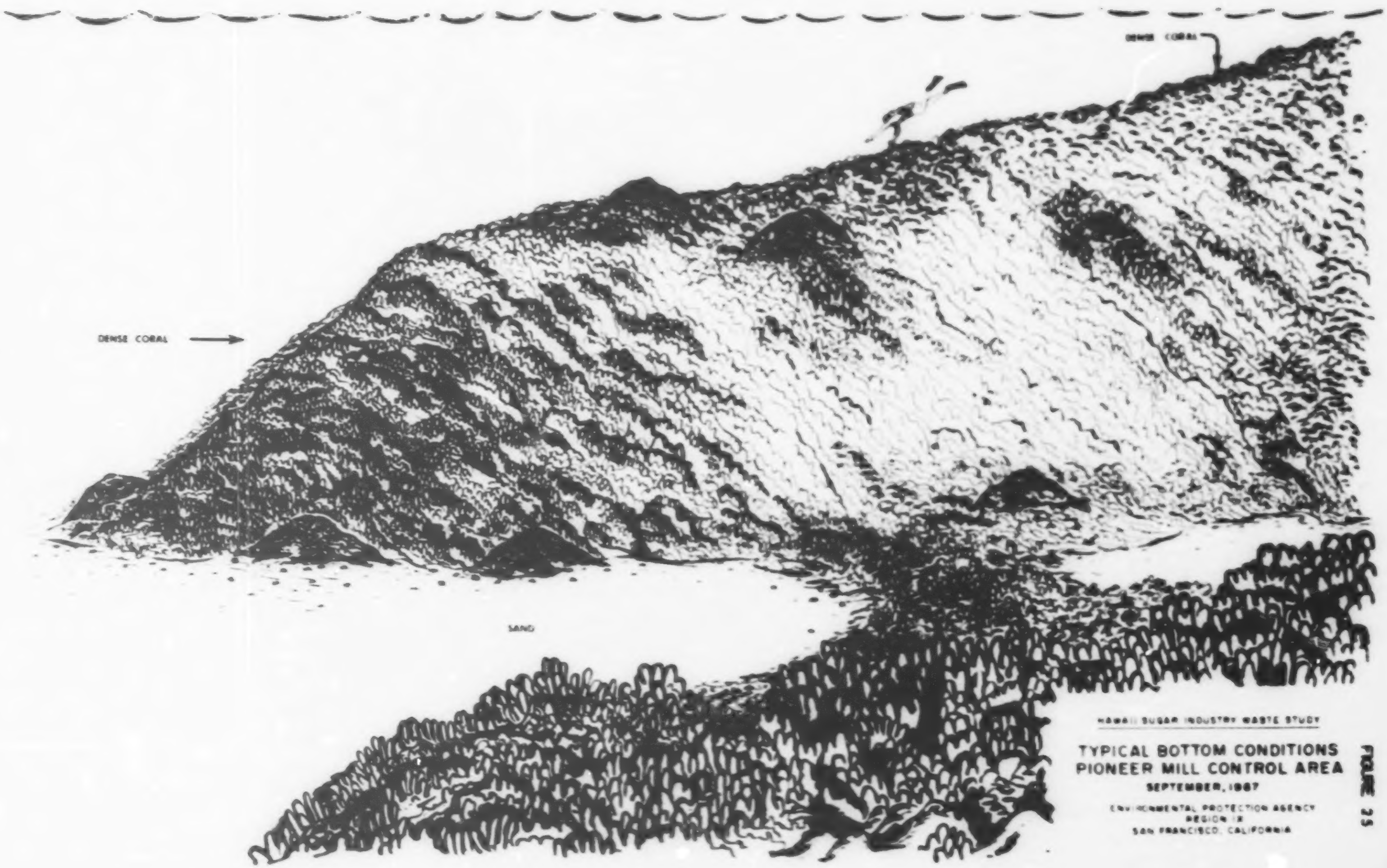

OUTFALL
DIMINISHING CORAL DENSITY
DENSE CORAL

FIGURE 24

HAWAII SUGAR INDUSTRY WASTE STUDY

BOTTOM CONDITIONS
PIONEER MILL OUTFALL AREA
SEPTEMBER, 19[illegible]

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

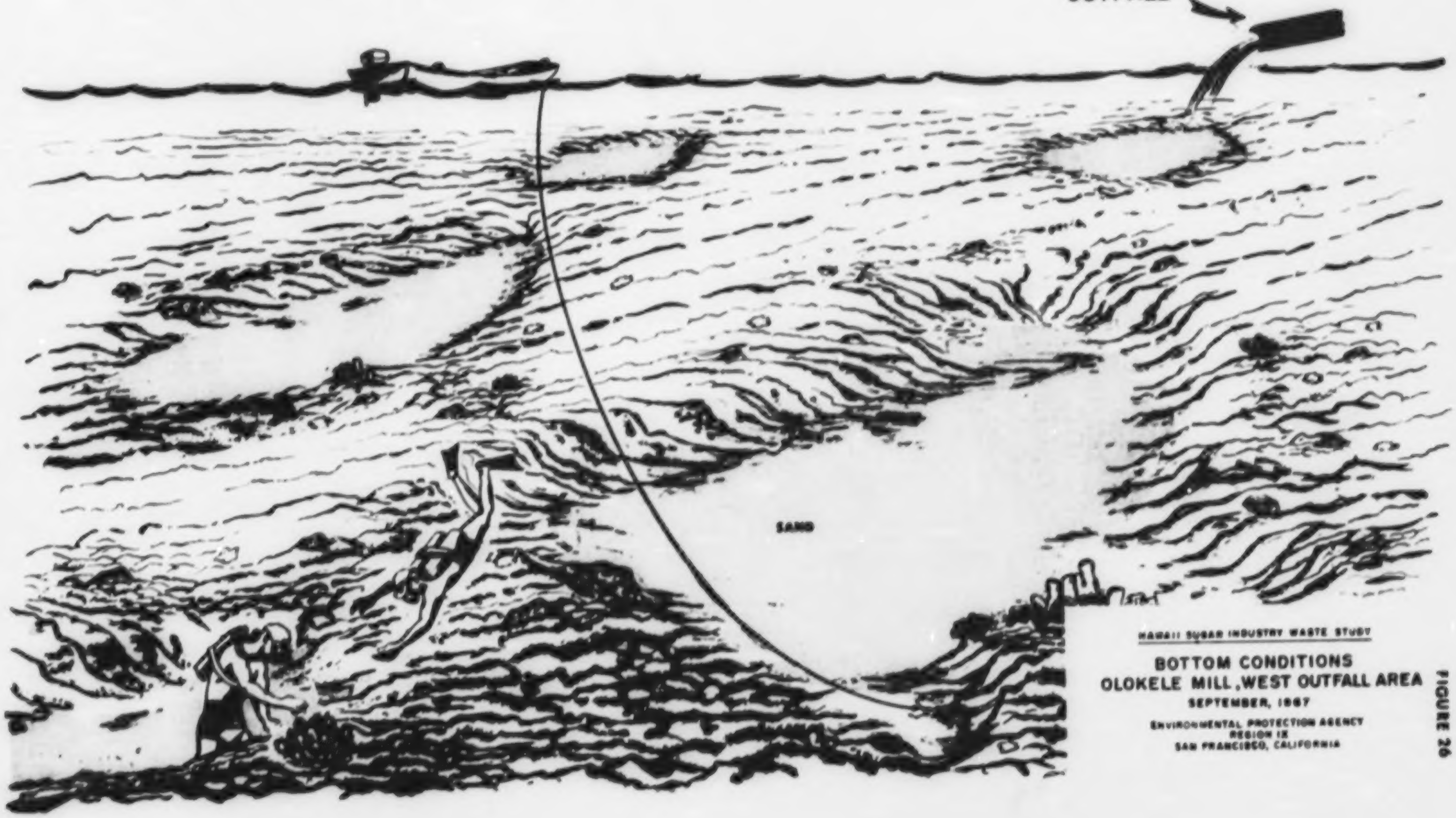

DENSE CORAL
DENSE CORAL
SAND

HAWAII SUGAR INDUSTRY WASTE STUDY

FIGURE 25

TYPICAL BOTTOM CONDITIONS
PIONEER MILL CONTROL AREA
SEPTEMBER, 1967

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA



HAWAII SUGAR INDUSTRY WASTE STUDY

BOTTOM CONDITIONS
OLOKELE MILL, WEST OUTFALL AREA
SEPTEMBER, 1967

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

FIGURE 26

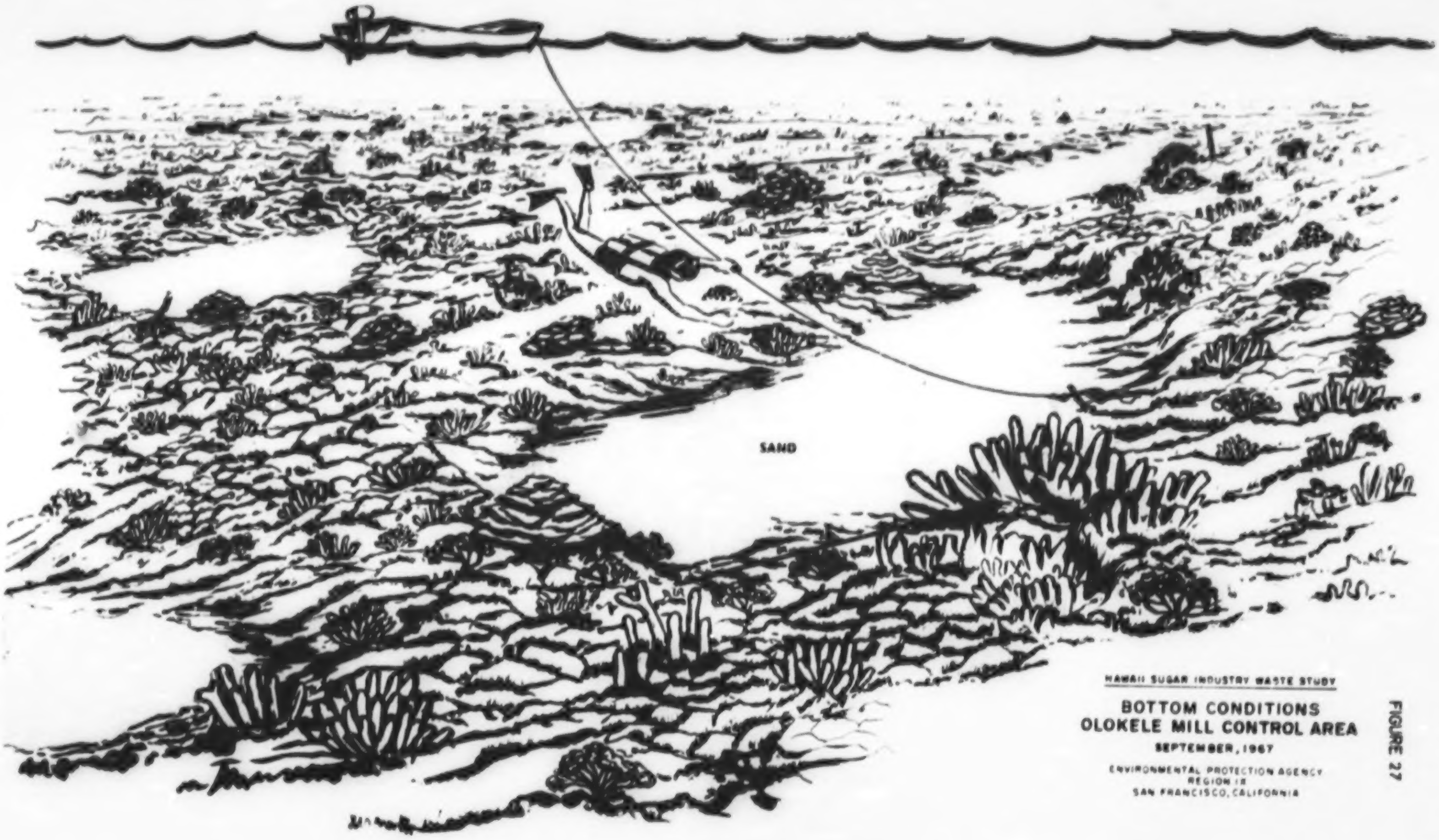


FIGURE 27

HAWAII SUGAR INDUSTRY WASTE STUDY

BOTTOM CONDITIONS
OLOKELE MILL CONTROL AREA
SEPTEMBER, 1967

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

healthy corals covering about 55 percent of the bottom in the control area (Plate 8). The control bottom also contained minor benthic algae and sponges.

The other distinctive bottom characteristic near the Olokele Mill outfall was a series of rocky ledges which resembled the bottom of the Poipu control area. The mill area was covered with fine silt with a few coral heads, and contained a number of sponges and some benthic algae, as opposed to the Poipu area which harbored a dense growth of coral heads, experienced relatively little silting and contained few sponges.

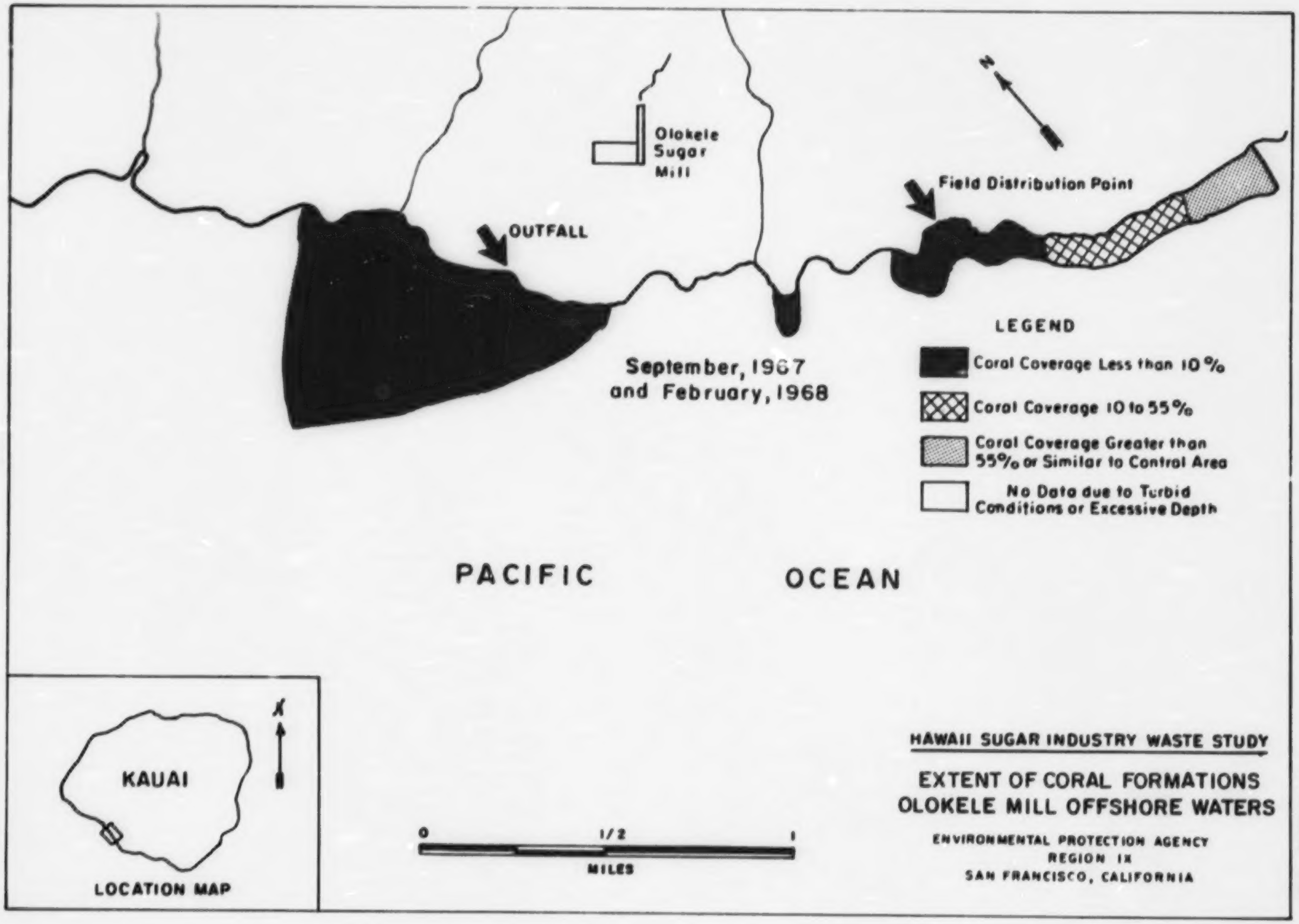
Due to turbidity only limited observations of bottom conditions were made near the Olokele Mill, but the observations which were made indicated the extent of coral formations as shown in Figure 28.

Discussion of Bottom Conditions: Honokaa Mill had no waste treatment facilities and consequently, its waste contained large amounts of trash, bagasse, and solids. Despite the open ocean currents, settlement occurred for about a quarter-mile area around the Honokaa outfall. Although fine layers of silt were observed at the other survey mills, no pockets of sludge were found there. This factor can be attributed to the clarification processes which wastes from the Pioneer and Olokele Mills undergo prior to discharge.

In addition to sludge deposits, the wastes from the survey mills caused biological modifications in the benthic communities, as demonstrated by comparisons with the various control areas. In all cases, the bottom conditions around the mill discharges were characterized by major reductions in coral growths and increases in sponges and benthic algae, two indicators of pollution. Coral reductions probably resulted from siltation and the diminished amounts of light which interfered with the life processes. The types and sizes of sponges found off the outfall areas are not observed in the clean waters of unaffected inshore areas. Their appearance would indicate an affinity of these organisms for a turbid and possibly over-enriched environmental condition.

Good observations were possible along the shoreline at the Honokaa Mill. From observation, the actual area of coral reef which was altered by mill discharges could not be precisely determined. It was observed that within 0.75 mile along the shoreline the coral was undamaged. Observations at the Pioneer Mill showed unaffected coral at 300 yards from the outfall. Less is known about the area of influence at Olokele Mill, although available data (Figure 28) show

FIGURE 28



Olokele Sugar Mill
OUTFALL
Field Distribution Point
N
September, 1967
and February, 1968
PACIFIC OCEAN
LEGEND
■ Coral Coverage Less than 10%
▩ Coral Coverage 10 to 55%
▨ Coral Coverage Greater than 55% or Similar to Control Area
☐ No Data due to Turbid Conditions or Excessive Depth
0
1/2
1
MILES
KAUAI
N
LOCATION MAP

HAWAII SUGAR INDUSTRY WASTE STUDY

EXTENT OF CORAL FORMATIONS
OLOKELE MILL OFFSHORE WATERS

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

that such a zone of influence extends for at least one mile from the discharge point.

FISH POPULATIONS

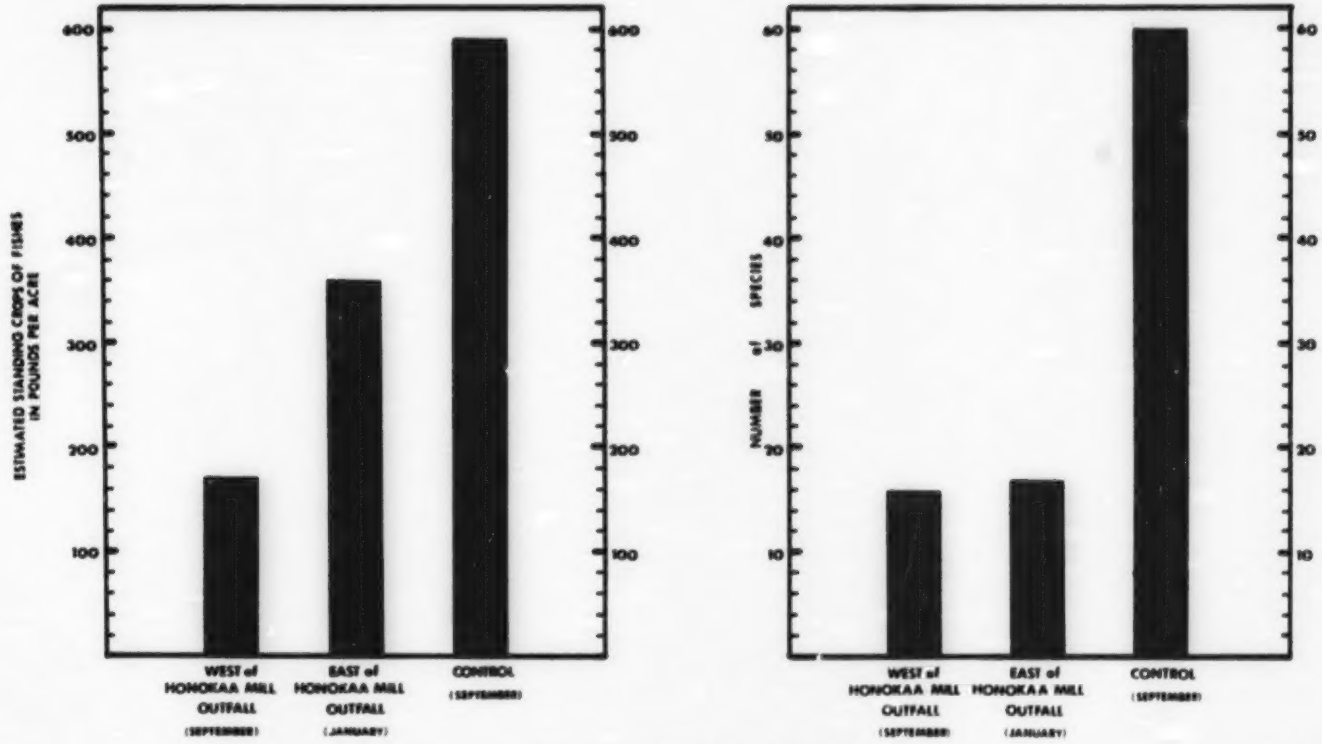
Underwater fish censuses were conducted at the discharge areas of the Honokaa, Pioneer, and Olokele Mills, and at the corresponding control areas. The procedure consisted of counting the number and size of various species of fish between the water surface and ocean bottom for a specific area. Proper orientation and direction for the census was obtained through the placement of a steel cable along the bottom of the survey areas. Standing crops of fish were computed from the size data using established formulas.

Honokaa Mill: Figure 29 presents the number of species of fish and the computed standing crops of fish found east and west of the Honokaa Mill outfall and also at the control area at Waimanu Valley. Data computed for the area west of the mill outfall were obtained during mill operations in September 1967, while data east of the outfall were gathered during the mill's winter shutdown in January 1968. The control data were obtained in September 1967. The data indicate that significantly larger amounts of fish life existed in the control area and that a larger standing crop of fish was found in the January survey of the mill waters, even though the number of species remained essentially unchanged.

Pioneer Mill: Observations of the number of species and standing crop of fish at the Pioneer Mill outfall and control area appear in Figure 30. The number of species of fish was only slightly reduced at the outfall area, while the calculated standing crop of fish was significantly reduced.

Olokele Mill: The ocean area off the Olokele Mill outfall has a relatively flat bottom area which is compatible with the area just east of the mill called the Olokele Control. The outfall area also contained a ledge area which was located by the mill off Kaumakani Point and was similar in conformation to the control area off Poipu Beach. Figure 31 presents the comparisions for both bottom conditions; results from Kaumakani Point outfall area are classed as estimates since the observations were not as thorough as those made for all other areas off Kauai.

FIGURE 29



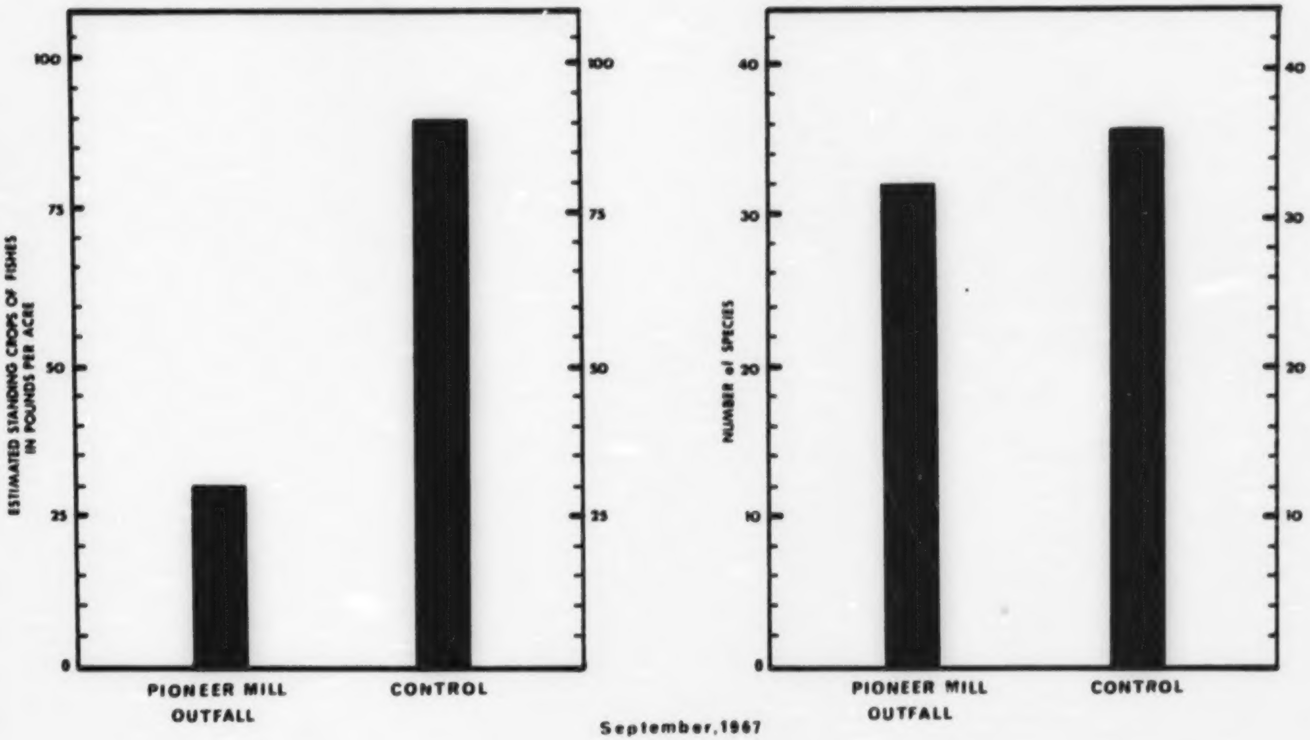
September 1967 and January 1968

HAWAII SUGAR INDUSTRY WASTE STUDY

RESULTS OF FISH COUNTS
HONOKAA MILL SURVEY

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

FIGURE 30



September, 1967

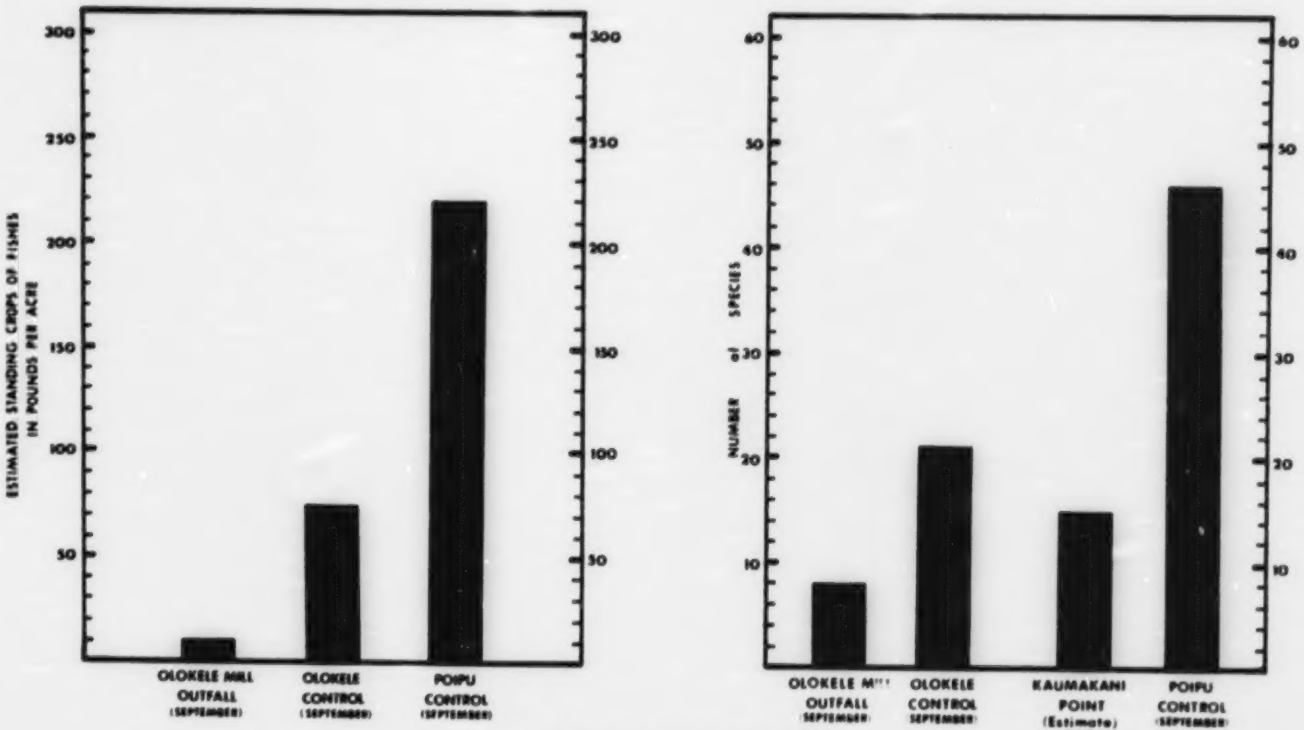
HAWAII SUGAR INDUSTRY WASTE STUDY

RESULTS OF FISH COUNTS

PIONEER MILL SURVEY

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

FIGURE 31



June and September, 1967

HAWAII SUGAR INDUSTRY WASTE STUDY

RESULTS OF FISH COUNTS
OLOKELE MILL SURVEY

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

Significantly greater numbers of species were observed in both control areas than were observed at their respective outfall areas. No estimate was made for standing crops of fish off the Kaumakani Point outfall area. Significantly lower standing crops of fish were, however, found at the Olokele outfall area than at the related Olokele control area. The Poipu control area contained a crop of highest numbers of fish of all control areas on Kauai.

Discussion: In all cases, it was found that there was less fish life near the mill outfalls than in the various control areas. East of the Honokaa Mill outfall, the number of indidivual species of fish dropped sharply while the standing crop changed by a lesser amount. The large standing crop noted at the Honokaa Mill could be attributed primarily to a large number of a "wandering school" species of fish which was in the area at the time. At Pioneer Mill, the number of species did not appreciably change, although the standing crop was observed to be considerably diminished.

It is believed that the two primary reasons for the observed decreases in the diversity and volume of fish were: (1) the absence of coral growth and other benthic life which limit the sources of food and shelter for the fish, (2) the turbidity around the mills which inhibits the ability of fish to locate food. This latter observation is particularly true since most local species are clear-water specimens which visually locate their food.

To summarize, the mill discharges cause depletions in both the quantity and diversity of fish life in the vicinity of the mill outfalls. The degree of this reduction bears a direct relation to the degree and extent by which discharges affect the bottom area.

VIII. BIOASSAYS

Acute bioassays were conducted to determine the effect of cane wash water on four species of local fish. The results from these tests appear in Table 7, where the median tolerance limit (TLm) is defined as the concentration in which 50 percent of the fish survive at the indicated time interval.

Ninety-six-hour acute toxicity bioassays were conducted to test the short term toxicity of industrial or other wastes on selected species of fish. These tests do not take into account factors such as temperature differentials, effect on fish-food organisms, chronic or long-term effects, breakdown of toxic materials with time, and oxygen depletions in the tanks. The latter two factors were partially compensated for by aeration and replacement of the wastes every 24 hours, when possible.

The most serious shortcoming of the 96-hour acute toxicity bioassay, however, was its inability to determine the long-term effect which constant exposure would have on a species of fish. In some basic research projects, this problem is met by actually exposing fish to definite renewed concentrations of a waste for periods greater than 30 days. When this procedure is impractical, an "application factor" is applied to the TLm to adjust for the above condition. Current practice designates applying a factor of 10 to the 96-hour TLm; however, a higher factor should accordingly be applied to shorter duration values. Table 7 indicates the percentage dilution under various application factors.

TABLE 7-BIOASSAY RESULTS

		Application Factors		
Species	TLm	10	25	100
Tilapia	>75% (96 hrs.)	>7.5%	>3%	>.75%
Aholehole	>75% (96 hrs.)	>7.5%	>3%	>.75%
Mullet	>75% (96 hrs.)	>7.5%	>3%	>.75%
Nehu	6-10% (48 hrs.)	0.6-1.0%	0.24-0.4%	0.06-0.1

Findings: The Tilapia, Aholehole, and Mullet fish exhibited an ability to live in almost 100 percent sugar mill waste for a period of 96 hours, if adequate aeration was supplied. Even with a conservative application factor of 25, indications show that these fish could survive in a permanent environment consisting of 3 percent mill waste.

All mills in the State, with two exceptions, discharge their wastes into either the ground or open ocean. Salinity and other measurements from the offshore studies indicate that a dilution of 3 percent is reached within a very short distance of the mill discharge points. Therefore, the mill waste discharges probably have very little effect on the first three species of fish shown in Table 7.

Nehu, a delicate species of fish, are the most important tuna bait fish in Hawaii, and results indicate that they have a much higher sensitivity to mill wastes than the other three species of fish tested. Since the TLm for Nehu of 6-10 percent only covers a 48-hour period, an application factor of 25 is not the conservative figure for this species. A conservative TLm figure for the Nehu would probably be the application factor of 100 or a dilution of 0.06-0.1 percent. Only two sugar plantations have mill wastes which significantly affect Nehu-inhabitated waters.

The discharge of excess irrigation water (tailwater) is a more significant problem than the mill wastes in those estuarine waters inhabited by the Nehu. These waters enter every major stream, bay, harbor, or inlet bordering irrigated canefields. During conduct of the bioassays, attempts were also made to expose Nehu to this type of waste, but such efforts met with little success. Because of the inability to maintain adequate controls, the bioassay results were not comparable. The tailwater wastes, however, were found to be similar for other parameters to the mill wastes and it was therefore conceivable that their effects on the Nehu would be similar.

IX. RUNOFF STUDY

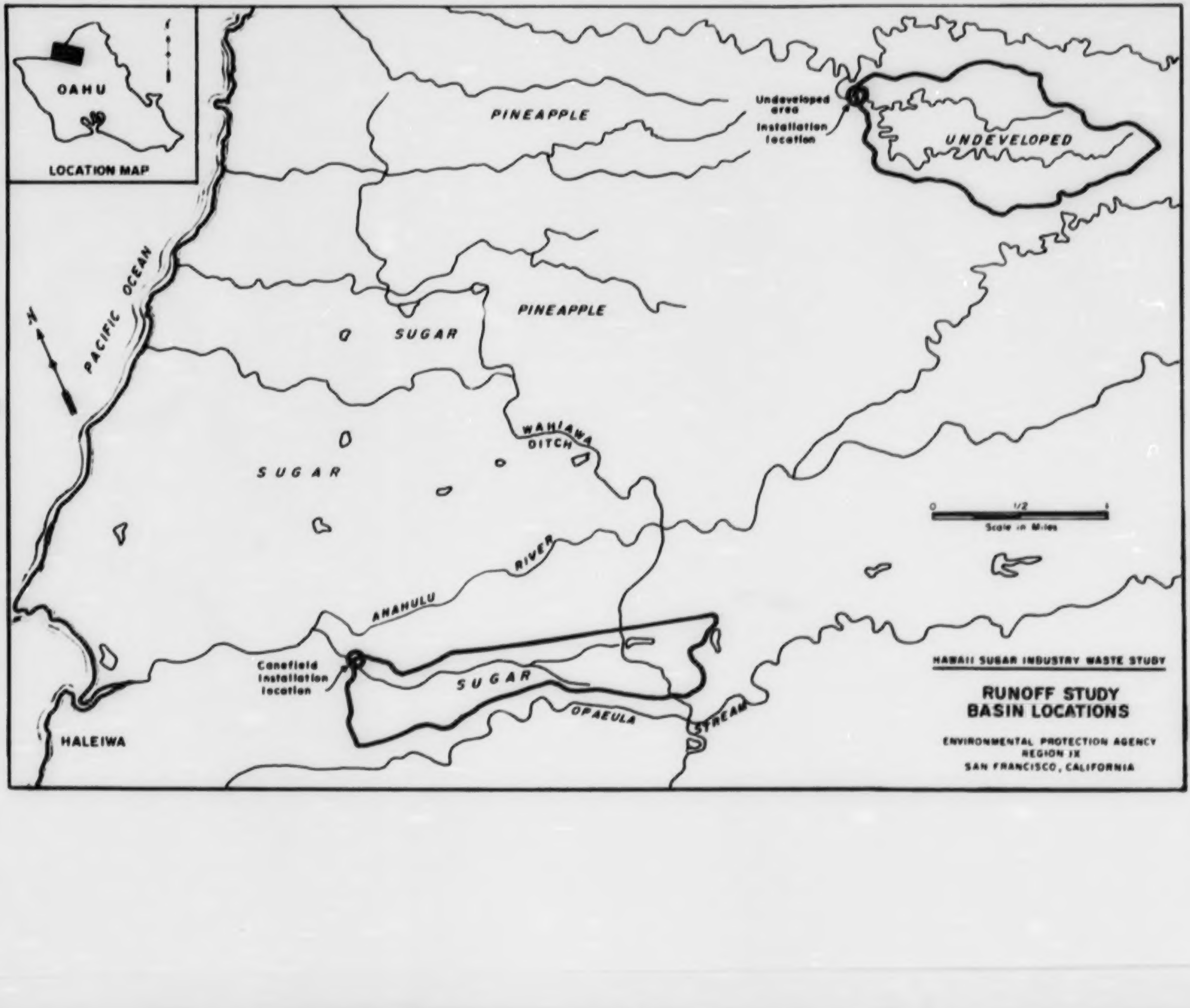
Runoff was monitored from two small drainage basins located in the northern portion of Oahu (Figure 32). The small basin indicated in the lower portion of the figure includes 0.55 square mile of sugar cane production and 0.24 mile of service roads, gulches, and irrigation flumes. The upper basin indicated in the figure is located in a more mountainous area and encompasses about 0.97 square mile of undeveloped land. Automatic sampling and monitoring equipment was placed at the outlets of both basins to monitor volume and contents of stormwater runoff.

The canefield installation is located in the fields of the Waialua Agricultural Company, a plantation having a fairly well developed soil and water conservation program. Its fields are laid out in a manner which forces surplus irrigation water or runoff to pond either in low areas of the fields or against embankments at the end of the planted furrows. Before any significant runoff occurs rainfall must be sufficient to cause overflow or breakout of the embankments.

The purpose of the runoff study was to provide comparative data on runoff from cultivated versus undeveloped land. Data were collected to answer questions concerning the sources of turbidity, high nutrient concentrations, depressed dissolved oxygen values, and other water quality parameters in the receiving waters after heavy runoff. It was hoped that some information would be gained regarding the controversy over whether sugar cane cultivation causes higher or lower concentration of pollutants in runoff, and whether cultivation practices cause higher or lower volumes of runoff water. During conduction of the study it was necessary to continue sampling into the 1968-69 rainy season to obtain necessary data. It should also be noted that during the second year the sugar cane basin was considerably less overgrown, a factor which would affect the rate of retention of water and sediment.

The 1967--1968 Study Period: The monitoring equipment was installed by November 1, 1967, the month marking the beginning of the rainy season in Hawaii. It was hoped that six significant discharges would occur at both study locations during the November-May period. These discharges did subsequently occur at the mountainous, undeveloped site, however, only one period of runoff occurred at the lower canefield site. Data gathered during the initial season indicated the following:

FIGURE 32


LOCATION MAP
OAHU
PACIFIC OCEAN
N
PINEAPPLE
PINEAPPLE
SUGAR
SUGAR
SUGAR
UNDEVELOPED
Undeveloped area Installation location
WAHIAWA DITCH
ANAHULU RIVER
OPAEULA STREAM
Canefield Installation location
HALEIWA
0
1/2
1
Scale in Miles

HAWAII SUGAR INDUSTRY WASTE STUDY

RUNOFF STUDY
BASIN LOCATIONS

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

(1) The undeveloped basin could retain over 90 percent of the volume of a 4-inch rain (24 hours) if there was no antecedent precipitation. More than 80 percent runoff occurred, however, if significant antecedent rainfall had previously occurred.

(2) The canefield terrain could retain over 80 percent of a 3.5-inch (12 hours) rain.

(3) Suspended solids values from the undeveloped terrain ranged from 10 to 240 mg/l during the year, while settleable solids values range from less than one to 140 mg/l (Table 8).

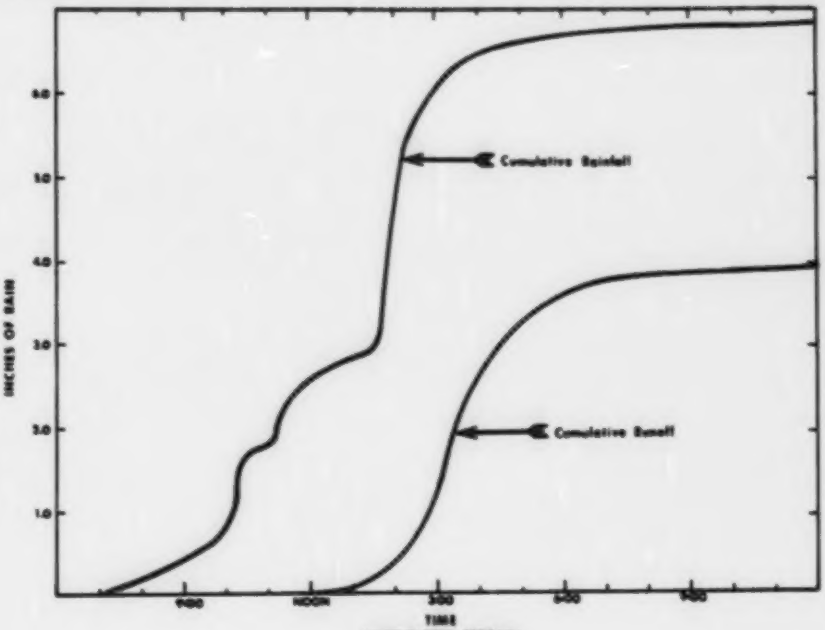
(4) Maximum and **minimum** values of concentrations for nitrogen and phosphorus were found to be similar to those in wastes from the mills themselves (Table 8).

The 1968-1969 Study Period: Two periods of significant runoff were observed on January 2-4, 1969, and on February 1, 1969. The former storm resulted in water levels sufficiently high enough to briefly activate the automated equipment, but the samples obtained were inadequate for anlaysis and this discharge therefore will not be covered. The February discharge, however, provides the first data for a near-ideal comparison between the two sites because of the relatively equal and heavy rainfall which occurred at both locations at nearly the same time. Table 9 and Figures 33 and 34 present data for the storm of February 1, 1969.

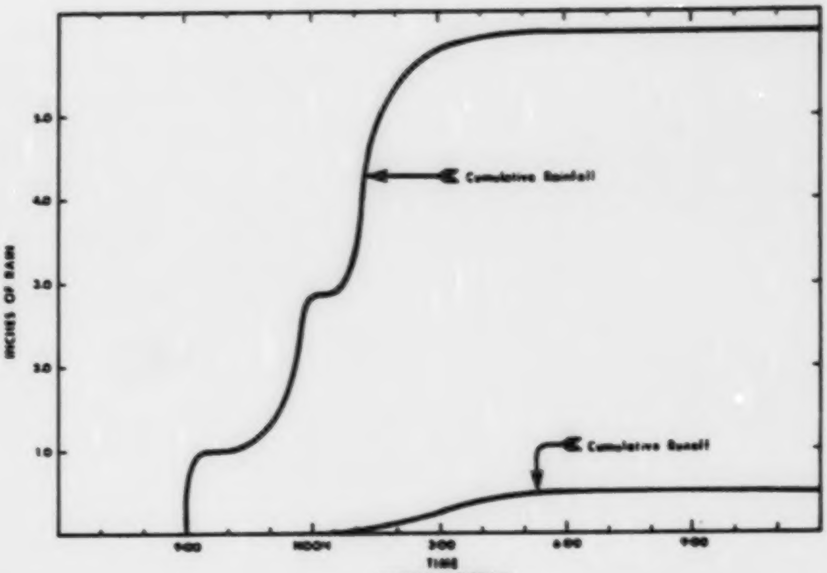
Discussion of Runoff Study: From Figure 33 it can be seen that the canefield terrain is able to retain a very high percentage of the rainfall. In one instance, over six inches of rain fell on the canefield basin during a 9-hour period and 0.45 inch of runoff occurred, representing about 7.5 percent of the total accumulated rainfall. During the same storm, about 3.7 inches or 55 percent of the rainfall on the undeveloped basin was converted into runoff despite the fact that roughly the same intensity and accumulation of rainfall occurred on both basins.

During a storm, both the canefield and undeveloped basins can absorb the initial two inches of rainfall. After this absorption, however, the canefield retains a higher amount of the precipitation than does the undeveloped basin. In this case this may be due to the fact that the slope of the land is not as great in the canefield. Also the conservation measures practiced by the plantation have a significant role in retention of runoff.

FIGURE 33



UNDEVELOPED TERRAIN



CANEFIELD TERRAIN

Note: Rainfall of Feb 1,1969

HAWAII SUGAR INDUSTRY WASTE STUDY

RAINFALL VS RUNOFF
UNDEVELOPED AND CANEFIELD TERRAINS

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

TABLE 8-MAXIMUM AND MINIMUM ANALYTICAL CONCENTRATIONS, RUNOFF STUDY: 1967 - 1968

	UNDEVELOPED TERRAIN		CANEFIELD TERRAIN	
Analysis	Range of Values	No. of Analyses	Range of Values	No. of Analyses
Total Solids (mg/l)	56-570	26	-	-
Suspended Solids (mg/l)	10-240	21	-	-
Settleable Solids (mg/l)	< 1-140	17	-	-
Chemical Oxygen Demand (mg/l)	20-153	22	160-253	4
Total Organic Carbon (mg/l)	5-71	26	64-116	5
Ammonia Nitrogen (mg/l) (as N)	< 0.1-0.4	25	<0.1	5
Kjeldahl Nitrogen (mg/l) (as N)	0.3-4.1	27	1.2-2.6	5
Nitrite Nitrogen (mg/l) (as N)	<0.05-.08	25	0.02-0.16	5
Nitrate Nitrogen (mg/l) (as N)	.04-.92	25	0.16-0.33	5
Ortho Phosphate (mg/l) (as P)	.003-.08	28	0.025-0.07	5
Total Phosphate (mg/l) (as P)	.02-1.68	31	1.9-3.5	5
Arsenic (ug/l)	<10	28	<10	5
pH (units)	5.6-7.1	20	6.7-8.1	4

Total Periods of Observation:

Undeveloped Terrain-6
Canefield Terrain -1

Figure 34 portrays the discharges of suspended solids from the two study basins during the February 1969 storm. Each vertical bar represents a sample taken by the automated apparatus. Samples taken hourly at the undeveloped site and every 30 minutes at the canefield location account for the differences in bar widths. The solid bars present accumulated discharge during the particular time increment. Cumulative discharge values are independent of bar width and comparisons for total discharge can therefore be made directly between the diagrams.

Despite the relatively small amount of flow from the canefield terrain, over 210 pounds of suspended solids per acre were discharged from the site. Comparison of both Figures 33 and 34 show that flow from the undeveloped site was eight times as great as flow from the canefield site, while the discharge of suspended solids was only about 1.5 times as great on a unit acre basis. This results from the high concentration of suspended solids contained in the runoff from the canefield terrain.

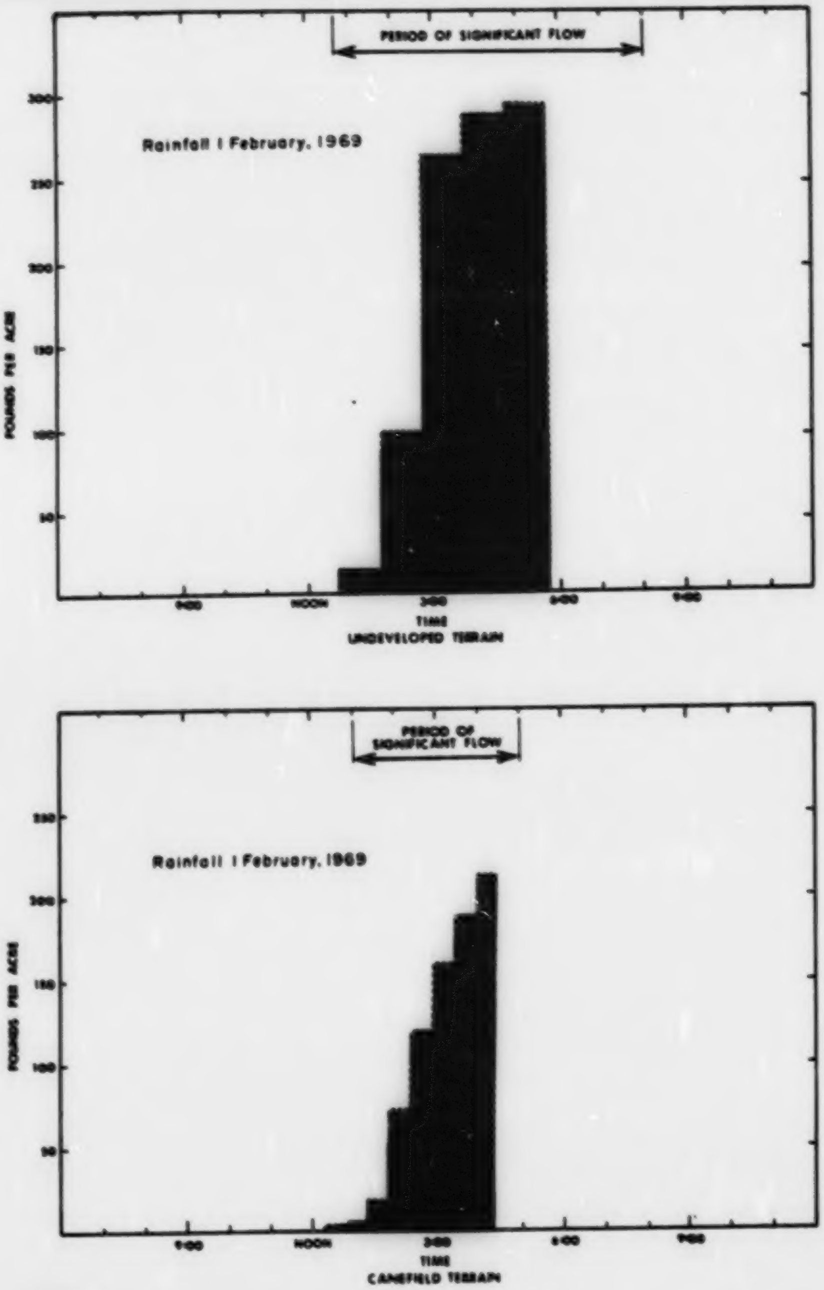
Table 9 contains data from the settleable solids analyses. In all of the canefield samples, the suspended solids were composed of more than 50 percent settleable material. Three out of five samples from the undeveloped site had settleable solids fractions less than 50 percent of the suspended solids value.

Observations of the storm of February 1, 1969 indicated a very similar heavy rainfall pattern at both study locations which approximated ideal conditions for comparison. Furthermore, U.S. Weather Bureau climatological records for the area indicated that a storm of this intensity and duration (6 inches in 6 hours) generally occurred once every seven years. It was, therefore, a fairly rare and intense storm. To summarize:

(1) The canefield site has the ability to retain significantly larger amounts of rainfall than does the undeveloped terrain.

(2) When runoff occurs from the canefield site, the solids concentration of the discharge is considerably greater than the concentration of runoff from the undeveloped basin. The solids content of the canefield runoff is at a sufficient level so that the total discharge of solids approaches that of the undeveloped terrain, despite the higher volume of discharge at the latter site.

FIGURE 24



LEGEND

■ CUMULATIVE DISCHARGE

■ INCREMENTAL DISCHARGE

HAWAII SUGAR INDUSTRY WASTE STUDY

SUSPENDED SOLIDS DISCHARGE
UNDEVELOPED AND CANEFIELD TERRAINS

ENVIRONMENTAL PROTECTION AGENCY
REGION IX
SAN FRANCISCO, CALIFORNIA

TABLE 9-MEASUREMENTS OBTAINED FROM RUNOFF OF FEBRUARY 1, 1969

Undeveloped Terrain

Sample Time	Discharge CFS	Susp. Solids mg/1	Sett. Solids mg/1
1310	185	234	81
1410	380	575	467
1510	870	552	328
1610	490	121	48
1710	185	55	24

Total Discharge: 9,700,000 cu. ft.

Cane Field Terrain

Sample Time	Discharge CFS	Susp. Solids mg/1	Sett. Solids mg/1
1200	10	1580	1024
1230	10	1730	1022
1300	11	1800	1196
1330	22	1140	604
1400	140	2640	2056
1430	80	2470	1350
1500	90	2560	1540
1530	60	2300	1196
1600	40	2640	1412
1630	22	-	-

Total Discharge: 875,000 cu. ft.

X. SELECTED BIBLIOGRAPHY

1. ULTRAMAR CHEMICAL LABORATORY FOR TETRA TECH INCORPORATED, August 1968, Water Quality Study - Keehi Lagoon and Vicinity of Ahua Point.

2. MURODA AND TANAKA, INC., January 15, 1965, Preliminary Severage Master Plan Feasibility Study for Honokowai and Surrounding Area - Lahaina, Maui.

3. SUNN, LOW, TOM AND HARA, November 1964, Report on Oceanographic Study for Kapaa Ocean Sewer Outfall - Kapaa, Kauai.

4. SUNN, LOW, TOM AND HARA, October 1, 1963, Oceanographic Studies Sewage Disposal for Hilo, Hawaii.

5. SUNN, LOW, TOM AND HARA, June 1962, Report on Oceanographic Survey and Study Relative to Sewage Disposal for Waianae, Oahu.

6. BELT COLLINS & ASSOCIATES - HOLMES & NARVER, December 1959, Kailua Ocean Outfall Sewer, Ocean Portion.

7. MAUI COUNTY DEPARTMENT OF PUBLIC WORKS, September 1965, Severage Feasibility Study and Master Plan for the Kihei Area of Maui.

8. HAWAII INSTITUTE OF GEOPHYSICS - INTERIM REPORT, January 1963, Currents around the Hawaiian Islands.

9. HAWAII INSTITUTE OF MARINE BIOLOGY, June 1968, A Descriptive Study of the Physical Oceanography of Kaneohe Bay, Oahu, Hawaii (M.S. Thesis of Karl H. Bathen).

10. KENNEDY ENGINEERS, March 1967, Report on Hawaiian Sugar Factory Waste Receiving Water Study - Prepared for Hawaiian Sugar Planters Association.

11. HAWAII DEPARTMENT OF HEALTH, February 1, 1967, Public Hearings on Water Uses and Standards of Water Quality for Maui County Waters.

12. BOARD OF AGRICULTURE AND FORESTRY, DIVISION OF FISH AND GAME, 1953, Survey of Industrial and Agricultural Water Discharged into the Coastal Waters of Maui.

13. BOARD OF COMMISSIONERS OF AGRICULTURE AND FORESTRY, DIVISION OF FISH AND GAME, 1949, Preliminary Report - Survey of Pollution in the Coastal Waters of Kauai.

14. TERRITORIAL DEPARTMENT OF HEALTH, BOARD OF AGRICULTURE AND FORESTRY, DEPARTMENT OF PUBLIC WORKS, 1947, Joint Report on the Survey of Mill Waste Disposal and Its Contamination of Sea Areas around the Island of Hawaii.

15. JOURNAL WATER POLLUTION CONTROL FEDERATION, Vol. 37, April 1965, Industry Idea Clinic, P-508.

16. CALIFORNIA STATE WATER QUALITY CONTROL BOARD, Publication 3-A, 1963, Water Quality Criteria.

17. FEDERAL WATER POLLUTION CONTROL ADMINISTRATION, April 1968, Water Quality Criteria - Report of the National Technical Advisory Committee to the Secretary of the Interior.

18. ASSOCIATION OF AMERICAN PESTICIDE CONTROL OFFICIALS INC., 1966, Pesticide Chemicals Official Compendium.

GPO [illegible]